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FISH AND GAME
SPECIAL BULLETIN

DIVISION OF FISH AND GAME
Board of Commissioners of
Agriculture and Forestry
Honolulu, Hawaii

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FISH AND GAME

S P E C I A L B U L L E T I N

NUMBER 2

APRIL 5, 1950

DIVISION OF FISH AND GAME

Board of Commissioners of
Agriculture and Forestry

Honolulu, Hawaii

PREFACE

The research staff of the Territorial Division of Fish and Game has been engaged in a number of research projects concerned with the conservation or better utilization of the fisheries of Hawaii. None of these projects have been completed; however, some of the information obtained so far, it is felt, would be of interest to both sport and commercial fishermen. Hence, it was decided to set forth this information in Special Bulletins of the Division of Fish and Game of which this is Number 2, parts 1 to 4.

From time to time it is planned to issue additional bulletins, not only on the fisheries of Hawaii, but also on wildlife research. These bulletins are available upon request.

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A PRELIMINARY REPORT OF THE DIVISION OF FISH AND GAME BAIT PROGRAM
Part 1. Summary of Field work with special reference to Hilo Harbor nehu scarcity

Division of Fish and Game

FISHERIES PROGRESS REPORT I, No. 1, Nov. 15, 1949

Territory of Hawaii
Board of Commissioners of Agriculture and Forestry
Honolulu

FISHERIES PROGRESS REPORT I, NO. 1, NOV. 15, 1949

PRELIMINARY REPORT OF DIVISION OF FISH AND GAME BAIT PROGRAM

By J. P. Welsh

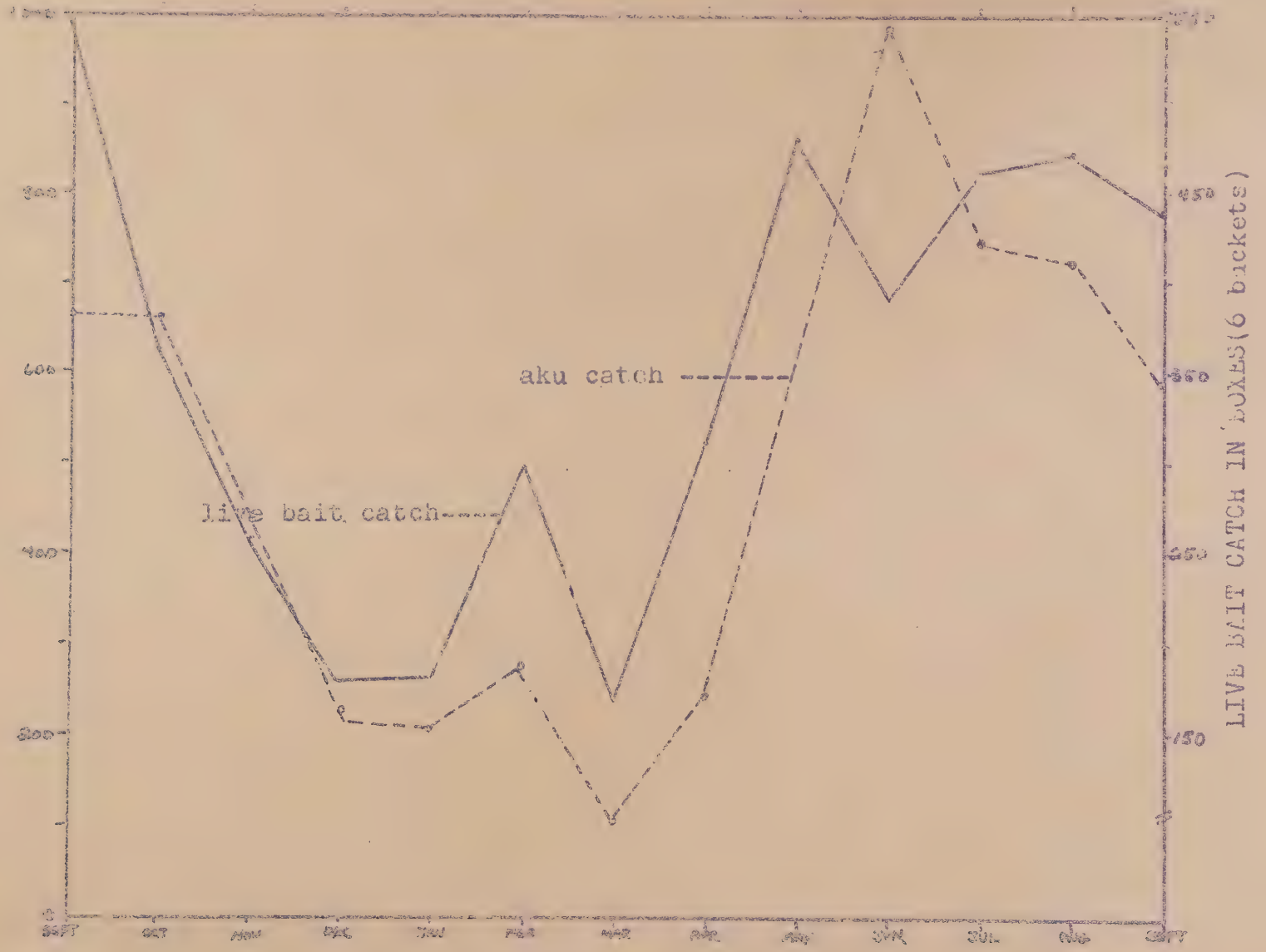
In a study of the Hawaiian Aku Fishery made by the Division of Fish and Game, it was found that a high correlation exists between the weight of aku caught and the amount of live bait available to the fishery (See Graph 1). This correlation served to illustrate the importance of an adequate supply of live bait in maintaining or increasing the catch of aku, a state of affairs of which the aku fishermen are well aware.

The staff of the Division of Fish and Game have attacked a number of problems involved in the live bait fisheries. While none of the investigations relating to these problems are yet completed, it has seemed desirable to issue a progress report on the results at hand.

Although progress reports on several separate investigations are included here, they all are concerned with live bait. One species of live bait, the nehu, is presently under a careful and detailed study by investigators at the University of Hawaii; however, that study has been largely concerned with the life history and biology of the fish. The work reported here has consisted, for the most part, of several surveys or investigations undertaken to answer fairly specific needs.

The problems involved in the bait fisheries fall into three categories: (1) Problems connected with finding live bait in adequate supply. Such matters as the habitat requirements of suitable bait fishes and the extent of such habitats together with the factors affecting the density of the bait fish populations in such habitats are of interest. (2) Problems connected with the

PLOT OF AKU CATCH AND LIVE BAIT
for the period from Sept., 1945
to Sept., 1946 inclusive



TIME IN MONTHS

capture and transportation of such bait fish to sea where it can be used for fishing. Considerable mortality of bait fish occurs as the result of capture and subsequent holding aboard the fishing vessel. (3) Problems connected with the use of bait in fishing. While no attempt to study possible means of increasing the efficiency of using live bait has been undertaken by the Division of Fish and Game, there are some fairly obvious possibilities. For example, it is not unlikely that a given quantity of live bait necessary to hold a school of aku from which eight men were fishing, would suffice to hold the same school if twenty men were hooking fish from it, and each individual fisherman should land an equal number of fish in both cases. The problem, as expressed above, is, of course, one of designing a vessel that twenty men can fish from efficiently, but is yet practical in other regards.

Two distinct types of bait fish are generally used in the local tuna fishery. The most common species used is the nehu (Engraulus purpureus), a local anchovy. These fish tend to occupy a habitat in which some fresh water enters the sea reducing the salinity of the surrounding salt water. This brackish water habitat probably tends to greatly reduce the area in which the nehu can be found and fished in Hawaiian waters. The nehu is the most important live bait fish, constituting approximately 95% of the total bait catch in 1947 throughout the Territory. The second major bait fish is the iao, (Pranesus insularum), a local silversides. This is the more hardy and generally larger of the two major bait fish and is therefore subject to less loss from those injuries incidental to capture and holding in a bait tank. However, the local fishermen prefer the nehu to the iao as bait for aku. The iao constitute about 4% of the total bait catch. The mosquito fish composed actually of a mixture of two species, Mollienesia latipinna and Mollieresia sphenops is used when the two major bait fish above are scarce. These

fish occur extensively in brackish water throughout the territory, especially in shallow marshy areas and in fish ponds. However, a special method of pinching the head of the individual bait fish is often used in order to make the mosquito fish act in such a manner to "draw" the tuna school to the aku boat in the correct manner. Young opelu (Decapterus pinnulatus) and young akule (Selar crumenophthalmus) are also used once in a while. The akule are used around Hilo and the opelu are caught at Kihei, Maui, and around the island of Niihau. Another fish used for bait is the piha (Spratelloides delicatulus). This is a non-estuarine fish, rather seasonal in its occurrence in Hawaii. Summer and early fall usually constitutes the piha "season". The open seas of the Kona sides of most islands constitute the baiting grounds for this fish. Mosquito fish, piha, opelu and akule constitute about 1% of the 1947 bait catch.

BAITING AREAS

A search of departmental catch statistics over a six month period determined the areas of major baiting operations during early 1948. These areas and the amount of bait they contribute to the fishery is given below:

*Jan.-June, 1948	% of total bait taken
Kaneohe Bay area	46.8%
Kihei, Maui	29.6
Pearl Harbor	7.1
Kawaihae, Hawaii	5.9
Ala Wai	4.1
Hilo, Hawaii	3.5
Incidental baiting areas	3.0
	100.0%

*Recent catch statistics reveal that the picture above has been considerably changed, especially in reference to the percentage of bait supplied to the fishery by Pearl Harbor. The U. S. Navy eased certain restrictions to the use of Pearl Harbor as a baiting ground during a period of extreme bait shortage early in 1949. Thus the 1949 picture of the relative importance of different areas in providing bait will show Pearl Harbor as a leading contributor.

AREAS OF COMMERCIAL IMPORTANCE FOR BAIT FISHING

Letter legend

I--Iao
P--Piha
N--Nehu
M--Mosquito fish

AREAS OF COMMERCIAL IMPORTANCE FOR BAIT FISHING

AREAS OF COMMERCIAL IMPORTANCE FOR BAIT FISHING

I--Iao
P--Piha
N--Nehu
M--Mosquito fish

AREAS OF COMMERCIAL IMPORTANCE FOR BAIT FISHING
N,I,P
KAWAIHAE
N,I,M
HILO
H A W A I I
P
KEALAKAKUA
I,P
HONAUNAU
I,P
HOOKENA
I--Iao
P--Piha
N--Nehu
M--Mosquito fish

A survey was made to determine the location of the areas in the main islands of the Hawaiian group where bait is taken for commercial purposes. This information was gathered from catch statistics and personal interviews of fishing captains in localized areas. The maps presented below give the location of these baiting grounds and an attempt has been made to show what species of bait fish are generally taken at each location.

BAIT TANKS

The aku fishing vessels are largely equipped with bait tanks of the open well type in which the water level inside is the same as the sea without, and circulation of water occurs through a number of screened holes in the bottom of the well. Such circulation is induced, when the boat is anchored, by its rocking or rolling and when underway by its forward motion. While live wells are inexpensive to operate, they do have a number of defects which, while not critical when live bait is held at low concentrations for short periods of time, become so when either the bait fish are overcrowded or held for more than a few days.

Some of the defects are: (1) Widely varying rates of circulation, depending on such factors as wind and sea conditions and speed of vessel. (2) Heavy slopping of water in the bait well, churning in air and knocking the fish about, when the vessel is subject to a heavy roll. (3) Dead or comparatively dead areas in the well corners where circulation is rather slight. Water enters and leaves the well by the same screened openings, which means that the last part of new water entering the well, being nearest the screened openings, is the first to leave. (4) A low bait capacity when judged on the basis of the number of gallons of water contained by the well.

The Division of Fish and Game has installed an experimental live-bait tank aboard the research vessel Makua in order to investigate possibilities of improving the holding techniques for live bait. This tank measures 51 1/8 inches

deep, 59 5/8 inches long, and 35 1/2 inches wide. It has a water capacity of approximately 470.43 gallons. An electrically driven power pump or a mechanically driven pump attached to the main engine are used to give forced water circulation to the tank. The mechanical pump is usually used when the ship is underway and the electric pump is used when the ship is tied up in port or on the baiting grounds. This use of power increases the operating cost and maintenance but the increase in bait-holding efficiency of a well-designed bait tank may eliminate any cost disadvantage. The inlet screen design coupled with the flow of forced circulation gives a complete circulation of fresh seawater to all parts of the tank--thus leaving no "dead" areas in the corners. The amount of water entering the tank is mechanically controlled by a rheostat connected to the electric motor driving the centrifugal pump. The mechanical pump may also be regulated. The range of the rate of flow is 25 to 100 gallons per minute, which at the highest rate gives a complete change of water within 5 minutes. Water circulation within the tank can thus be controlled to fit the needs of the bait fish under a variety of conditions. The tank is built with a receiving hatch at the top. The water level is raised to include this hatch as the only surface area within the tank. This eliminates surge within the filled tank which might injure the bait fish. (See diagram on next page). Although the tank is smaller than the live wells used on aku boats, it can hold up to 30 buckets of bait at a maximum water circulation of 100 gallons per minute. Five to seven buckets of bait is the capacity of most open-flow type of bait wells. It has been found to be advisable to mount the pump used for circulation below the waterline. This gives a positive head of water at all times within the pump chambers and intake line, thus preventing a suction effect which might produce air bubbles if a leak were present in the pumping system. A large intake pipe is also necessary to prevent this suction effect. Small air bubbles introduced by pumping cause a heavy mortality in bait fish. The outboard end of the water inlet should be mounted well clear of the ship's hull in a

streamlined housing. This prevents air bubbles from the ship's wake to enter the intake line. Dead and weak fish have a tendency to pile up at the screened outlet and block outgoing water if the outlet screen is too small for the volume of water going through it. If the outlet screen is designed to strain not more than 10 gallons of water per minute per square foot of area, little difficulty from this cause should be found. A flowmeter is being installed which will accurately measure and record the volume of water which enters the tank. This will make possible future work upon the determination of the exact amount of water which will provide an optimum living condition for a given amount of bait. Also, work will be possible to determine the effect of different oxygen tensions and salinities upon the bait fish.

Given below is a descriptive summary of the first introductory research efforts which have been carried out by the Division of Fish and Game.

The boat used in connection with this work was the M. V. MAKUA, research ship of the Division of Fish and Game. This vessel is 65 feet long overall and has a compliment of three crewmen. The lighting used to attract fish varies as different designs and intensities were tested for effectiveness. The areas under test are still being worked and this aspect of the work is expected to continue for a protracted time to adequately test all possibilities of opening up new baiting areas.

The field work that has been accomplished during this investigation may be summed up in the following chronological order and the results of the work is given with the description of the work done.

August 14, 1949

The new type of lift-net baiting gear was tried out at Kaneohe Bay opposite Coconut Island. A standard 250 watt light was used. One set of the net was taken just before dawn and with three men handling it about eight buckets of bait were taken. As this was the first use of the net, a good catch was not

expected. This not only tended to prove the feasibility of using such a net with a minimum of crew and effort.

August 25 - September 12, 1949

An extensive investigation of the decline of the bait in Hilo Harbor was carried out and the results of this investigation boiled down to a problem of pollution. Upon the request of the 1949 Territorial Legislature, a copy of the report given below was sent to the legislature for consideration. This project was carried out jointly with the Department of Zoology of the University of Hawaii.

INVESTIGATION OF BAIT AND OCEANOGRAPHIC
CONDITIONS IN HILO HARBOR

PURPOSE OF THE PROJECT AND RESULTS:

The investigation of the decline in bait fish in Hilo Harbor got underway August 25, 1948 with a conference between research workers of the Division of Fish and Game and local fishermen of the Hilo aku industry. The present conditions and fishing methods were compared with the bait fishing situation in the past. Changes in the physical condition of Hilo Harbor and the chemistry of the water in the harbor were defined.

It was brought to the attention of the research staff that great difficulty in catching bait was being experienced by the aku fishermen at Hilo. Initial investigation of catch reports indicated that in the last few years, a sharp decrease in the amount of aku landed in Hilo was evident. The conditions of the early 1948 aku season were especially disastrous. It was reasonable to assume—supported by the testimony of the Hilo fishermen—that the scarcity of available bait was responsible for this decrease in aku catch.

On August 25, 1948, the MV MAKUA, Division of Fish and Game research vessel, was sent to Hilo to carry out an investigation of the causes of this bait scarcity. Work was to include oceanographic sampling to determine the chemical and physical condition of the water in Hilo Harbor, bait catching and holding work to test the actual physical condition of the bait—fish, and observations of the physical

features of Hilo Harbor which may have a bearing upon the condition of the fishery. The facts arising from the completion of these three phases of the problem may be summed up as follows.

A tidal wave in 1946 destroyed the old Hilo Harbor breakwater. It was reported that the construction of the new breakwater was found to differ from the construction characteristics of the pre-tidal wave breakwater. The new breakwater was made with smaller rocks which prevented any appreciable circulation of fresh seawater into the bay in any other place than the ship channel. It was found that the Hilo Sugar Mill was dumping its bagasse and cane-washings directly into this ship channel. This cane trash and mud circulated freely into Hilo Harbor on the incoming tide. The old breakwater was constructed of larger, more loosely-fitting rocks which allowed a considerable wash from the open seas to enter and circulate in Hilo Harbor at many points, hence limiting the effects of trash in the harbor.

The research staff noticed the heavy turbidity of the Wailoa River which enters Hilo Bay. During the course of the observations of this river, it was noticed that a large number of bait fish were attempting to swim up the river from the bay. These fish quickly died when they had swum a few yards up the river. The water of the river at this time was extremely turbid. The next day the river water was quite clear and these dead fish were seen to cover a considerable area of the river bottom at its junction with Hilo Bay. This was said to be a common occurrence by the local fishermen. It is of interest to note here that the Canec Flintkote Company and the Hilo Gas Works dump their industrial waste products into the Wailoa River. During a recent shipping strike, the canec plant was forced to shut down and the observations made of the river at this time are included in the attached copy of a letter received by our Hilo Fish and Game

warden. (See attached copy).

In the six day oceanographic program covering the normal tide cycle of August 26-31, 1948, 198 water samples for salinity, temperature, oxygen concentration and chemical analysis were made. Sixty-six secchi disk readings were taken in conjunction with a light-meter to determine the turbidity of the water. Eleven bottom samples were analysed for evidence of harmful chemicals. To cover this work, eleven oceanographic stations were set up which covered Hilo Harbor baiting areas, areas of suspected pollution--such as the Wailoa River, Hilo Sugar Mill dumping ground and the local sewer outlet in the bay--and the immediately adjacent area outside of the breakwater. Samples at each station were taken at three depths to determine the depth of any changes in the chemistry of the water.

The results of the secchi disk readings showed that clarity of water was progressively less as the readings were taken from the Hilo docks to the Hilo Sugar Mill outlet. In previous years before the war, the best baiting grounds were in an area from the present location of the Hilo Sugar Mill south to the Wailoa River. This area is now useless to the fishermen as a baiting area due to the trash-pollution of this water and the absence of bait in the area. The only remaining baiting areas at present are in the zone of clearest water around the Hilo docks in the southernmost portion of the bay. The old baiting areas seem to be barren of bait fish and are therefore not used by the local people.

The oxygen analysis indicated an expected increase in oxygen-content of the water at the surface area but the differences were not enough at other depths to be significant. Salinity results showed a lower salinity in a layer of water about eight feet thick lying at the surface of the bay. Brackish water is considered beneficial to the bait-fish and necessary to their successful spawning (hence the interest in the fresh-water supply of the Wailoa River). A normal temperature gradient was found in all stations at all depths. The bottom samples

showed a carpet of bagasse to cover the bottom of the parts of Hilo Bay near the Hilo Sugar Company outlet, but hydrogen sulfide tests showed the absence of this harmful chemical which might be suspected from the rotting of the bagasse.

Baiting operations were carried out by the Makua from August 26 to September 9, 1948. On August 26, approximately 12 buckets of bait were taken in one set of the net in the areas around the Hilo dock. On the same night, the aku boat Tenjin Maru made three sets of their net further out in the bay and obtained only three buckets of bait. It is interesting to note that the aku boat was using a 40 Watt light in comparison with a 250 Watt light used on the Makua. The extreme turbidity of the water might indicate a great difference in attracting power between the two lights. Improvement of gear by the two aku boats now operating in Hilo might increase their bait catch.

The bait lived well in our bait tank over a 14 hour period. About 14 buckets of bait were caught on the next baiting operation on September 8 at the Hilo docks with one set of the net. This bait showed a rather high initial mortality when held off the Wailoa River. An almost complete mortality occurred over a period of 40 minutes when the bait was held with surface water from near the Hilo Sugar Mill cane-washing outlet. About four buckets of bait were caught with one set of the net on September 9 at the Hilo docks. The bait had a high mortality when held with water taken near the Hilo docks. This would indicate a general weakened condition of the bait itself. Mortality was accelerated when this bait was held in water pumped from the surface of the bay in front of the Hilo Sugar Mill outlet. Previous to this, the bait was held in water pumped from a depth of twenty feet in the same area and no immediate acceleration of mortality was noted. Water samples showed cane-washing to occur in a layer of about four feet over the surface of the bay in this area.

The thirty buckets of bait collected in three hauls of the bait net

indicate that our baiting operations were fairly successful. However, our baiting operations were conducted while the MAKUA was tied up to the Hilo docks, a location closed to baiting operations by commercial fishermen at that time. Since then, this area has been opened to commercial fishing by the efforts of the Board of Harbor Commissioners, the Board of Commissioners of Agriculture and Forestry and interested individuals in Hilo.

This investigation has indicated a general scarcity of bait in Hilo Harbor. It also has indicated that an improvement in fishing technique and gear might increase the bait catch to an appreciable extent. Oceanographic and chemical analysis failed to indicate any definite indications of the cause of the general weakness and scarcity of the available bait fish. It was found that a rather large amount of pollution was entering Hilo Bay but the exact effect was not determined by measurable chemical analysis.

Hilo, T. H.
October 28, 1948

Mr. Vernon E. Brock
Division of Fish and Game
Honolulu 1, T. H.

Dear Mr. Brock:

With the shut-down of the Canec Flintkote Company here in Hilo on the 23rd of this month and as per instructions by you on the sampling of live nehu in the Wailoa River for survival, I checked with Mr. Matsumo and other fishermen at the Fishing Docks and found these informations:

1. The morning of October 26th, schools of nehu came up the river and survived from about 10:00 A.M. to 7:00 P.M. of the same day, none seen to belly-up or die.

2. The morning of October 27th, schools of nehu came up the river and survived from about 8:30 A.M. to 11:00 A.M. of the same day, none seen to belly-up or die.

Mr. Matsumo believes that as long as the Canec Plant is closed down, more nehu will be coming up the river.

Very truly yours,

Eugene K. Burke
Senior Fish and Game Warden.

A SUMMARY OF THE REPORT ON HILO HARBOR BAIT INVESTIGATIONS

ABNORMAL PHYSICAL CHANGES NOTED IN CONDITIONS AT HILO HARBOR

1. The new breakwater is constructed of small rocks with a resulting reduction in circulation of sea water through the breakwater into the harbor.

2. Hilo Sugar Company is dumping its cane thrash and washings directly into the ship channel which washings are carried into the harbor by incoming tides.

3. The turbidity of Wailoa River is serious at certain times. Fish entering this river during such periods were noted to die soon after entering the river. However, those entering the river during times when the Canec Factory was closed down remained sometime and moved well up the river.

TESTS CONDUCTED

1. Turbidity test indicated increased turbidity from the direction of the Hilo Docks towards the Hilo Sugar Mill outlet.

2. Oxygen content of the water at all stations was not significantly different.

3. Water salinity showed an area of approximately 8 feet depth on the surface of the bay where water was less salty. This situation is conducive to the presence and growth of bait fish.

4. Temperature gradients at all stations were normal.

5. Bottom samples showed a carpet of cane bagasse covering parts of Hilo Bay near Hilo Sugar Company.

6. The poisonous gas hydrogen sulfide was not detected in the region of rotting bagasse.

HOLDING TESTS
WITH LIVE BAIT

1. Larger quantities of bait were obtained by the Kaka using a stronger light than those amounts obtained by aku vessels using weaker lights. The general turbidity of the water in baiting areas would indicate the need for stronger lights.

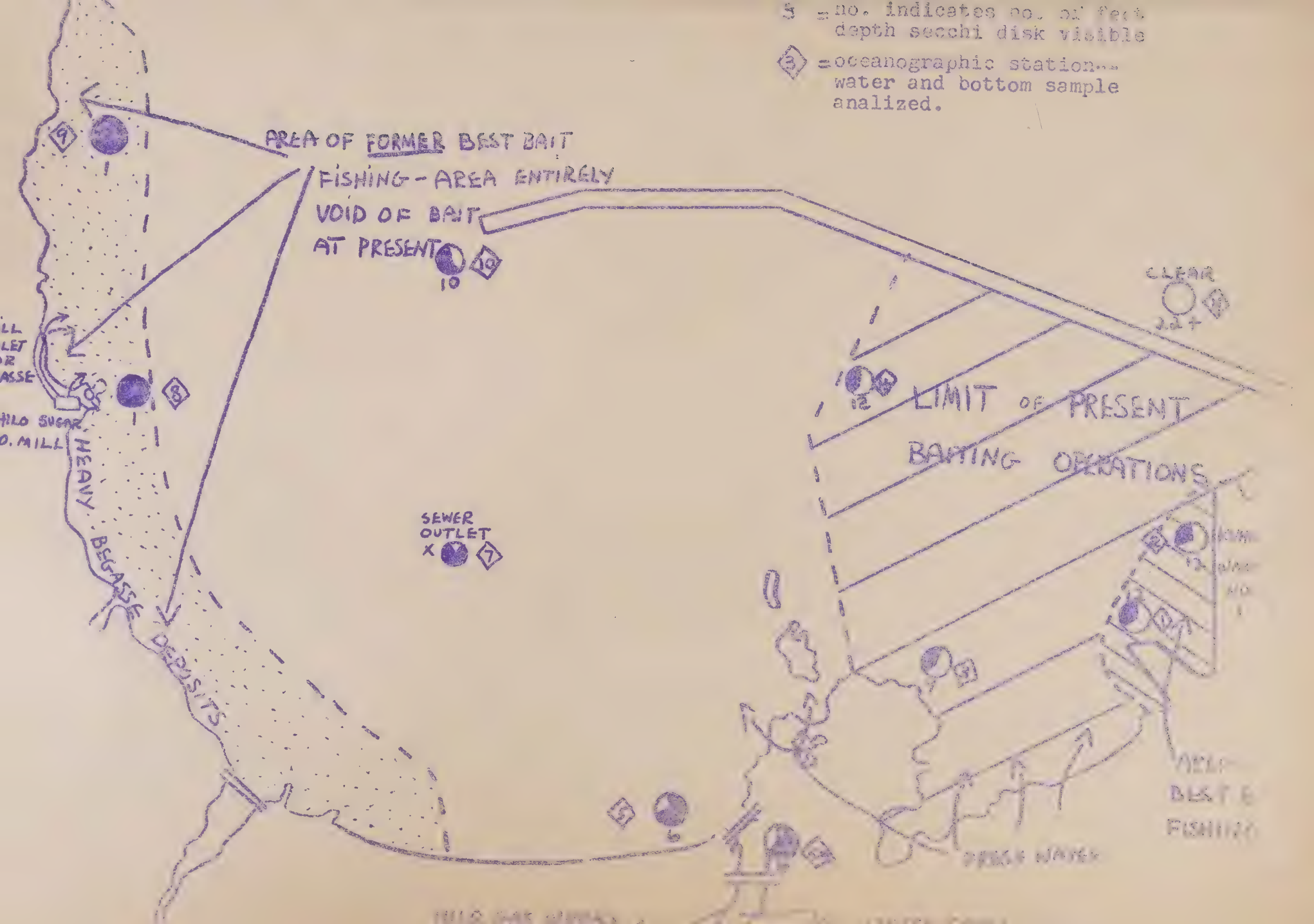
2. Bait obtained near the Hilo Wharf was held successfully for 14 hours in that region.

3. Bait held in the tank with water pumped from the surface of the bay near Hilo Sugar Company Mill outlet died within 40 minutes.

4. Bait held in the tank lived fairly well when water was pumped from a depth of 20 feet at the site of the Hilo Sugar Company cane-washing outlet.

GENERAL

Absence of bait in former good baiting grounds is likely a result of the high turbidity found in the ocean water as caused by various materials in colloidial form which are deposited in the ocean.


5 =no. indicates no. of feet depth secchi disk visible
3 =oceanographic station-- water and bottom sample analized.
AREA OF FORMER BEST BAIT FISHING-AREA ENTIRELY VOID OF BAIT AT PRESENT
10
CLEAR
LIMIT OF PRESENT BAITING OPERATIONS
SEWER OUTLET
HEAVY BEGASSE DEPOSITS
HILO SUGAR CO. MILL
BEST BAIT FISHING

September 14 - 16, 1949

A series of baiting operations were carried out at Kealakekua Bay on the Kona Coast of Hawaii. The Makua was anchored just off Napoopoo and the lift-net was used with a 250-Watt float light. Two sets were taken about dawn and the bait taken proved to be Piha (Spratelloides delicatulus). The first set took 15 buckets of bait but it was observed that the net "cut" the schooling fish and took only a portion of the bait around the light. Immediately, a second set was made and an additional 16 to 17 buckets of bait were taken. As this was all the bait the live-box on the Makua could take, fishing operations were stopped. Very good results were obtained by baiting a school of aku with the piha just outside of Kealakekua.

January 20, 1949

Baiting operations were carried out at Coconut Island in Kaneohe Bay. Three different types of lights were used. The first light was an ultraviolet 1000-Watt stage light hung over the water with a blue filter. This light strongly attracted the fish but the lack of visible light to the human eye made it hard for the fishermen to observe the actions of the bait around the light. It was found that the predatory fish tended to come right up to the light and to disturb the circling nehu. Next, the blue filter was removed from the light and the very bright light was allowed to shine directly into the water. This light had very great attractive power for both bait and any other kind of marine life. The bait tended to stay deeper and the predatory fish would not approach the bright circle of light on the edge of which the bait fish circled. It is interesting to note that a sizeable school of bait fish showed up at the light almost immediately. In addition to the bait, swimming crabs, squid and masses of zooplankton swarmed about

the light — showing the light's very great attractive power. Next, a floating standard 350-Watt/light was used in connection with a rheostat which enabled the fishermen to dim or brighten the light to any intensity that was desired. It was found that if the light was slowly dimmed during the netting operation, the bait fish moved in close to the light and were much easier to capture. However, if the light was dimmed too far in advance of the netting operation, the predatory fish moved in and broke up the circling nehu. The operation took about 30 - 35 buckets of nehu with one set of the lift-net. It is interesting to note that an aku boat during this test was within a few hundred feet of the Nakua using the standard light. The aku boat was able to capture only five buckets of bait all night.

March - June, 1949

A series of baiting stations are being held in Honolulu Harbor and Kalihi lagoon to determine the best areas of bait-fishing. Areas now closed to the aku boats are being investigated to determine their value as baiting grounds with the idea of a future opening to the aku fleet of any valuable areas. Negotiations are being carried out with the Federal Government in connection with this aspect of the work.

Baiting operations were carried out in Honolulu Harbor as follows:

February 28, 1949 - Outer end of Pier #2

2015 - on station, night-light on

2030 - numerous small mullet around light; water milky, current ½ knot

0200 - small fish and crustacea larvae very thick about the light

0500 - still many small mullet around light, no nehu or iao seen all night.

March 2, 1949 - Old Sand Island landing near harbor mouth

2020 - on station, night light on

2040 - small mullet and fish larvae around light, clear night, much wind, oil on surface of the water, iheihe thick around the light.

0500 - made net haul catching numerous small mullet, only very few nehu — about 30 individuals

March 7, 1949 - Inner end of Pier #2

2015 - on station, night light on

2100 - very few mullet at light, fish larvae thick

2215 - two large hihimanu at light circling and sounding, very few mullet

2400 - very few mullet, many crustacea and fish larvae

0500 - made net haul - moderate amount of mullet taken, few nehu - about 75 individuals

March 9, 1949 - Outer Waikiki end of Pier #5

2015 - on station, night light on

2100 - few mullet at light, water clear, no current, light N.E. wind

2300 - larvae thick around the light, few adult fish

0500 - made net haul - few mullet and about 48 adult nehu

March 22, 1949 - Outer Ewa end of Pier #7

2015 - on station, light on

2140 - water fairly clear, slight wind, rain. Very few fish around the light, larvae not too plentiful

2300 - rain continuing, very few fish coming around light

0300 - water very clear, more small fish coming around light

0500 - made net haul - many small mullet, manini and about 250 adult nehu, no iao.

March 29, 1949 - Outer end of Pier #12

2015 - on station, light on

2100 - plenty of small mullet and nehu

2400 - nehu school growing larger - estimated about 8-10 buckets

0200 - more nehu around light - current about ½ knot

0415 - made net haul, took about 5 buckets of nehu

April 18, 1949 - Outer end of Pier #15

2015 - on station, night light on

2400 - down stream current, water milky, few nehu around

0400 - nehu very thick around the light, estimated about 30 buckets

March 31, 1949

Baiting operations were carried out at Kihei, Maui, with a night light and the lift-net but no favorable results were obtained. It was felt by the fishermen aboard that the Makua was anchored too far from shore and too far into the direct force of the wind storm that was blowing at the time.

April 26, 1949

Baiting operations were carried out at Nawiliwili Harbor on Kauai opposite the commercial docks. The night light with attached rheostat was set about 9:00 P.M. and almost immediately a number of nehu were seen to start circling the light. It is interesting to note that the nehu also tended to come around the boat in the daytime when a small amount of animal palu was thrown into the water. The light was left in the water until 3:00 A.M. when a second investigation of the light revealed that the nehu had been replaced by a very large school of aholehole. These fish were either scared away or taken by an immediate set of the net. An hour later, a second set of the net was made and a small number of nehu were taken.

SUMMARY

The results of these preliminary surveys of the Hawaiian bait fishery may be summarized as follows:

A. The following species of fish employed as bait:

Nehu (Engraulus purpureus)	95%
Iao (Pranesus insularum)	4%
Piha (Spratelloides delicatulus), Mosquito fish (Mollienesia latipinna) and (Mollienesia sphenops), Young Opelu (Decapturus pinnulatus), Young Akule (Selar crumenophthalmus)	1%

B. Baiting is done in inside waters, bays and estuaries for nehu and iao; in open sea conditions for piha, opelu and akule; and in brackish water ponds and ditches for mosquito fish.

C. Kaneohe Bay, Pearl Harbor and Kihei, Maui are the major territorial baiting grounds.

D. Fishing techniques are somewhat cumbersome and night-light intensities are quite variable, leaving possible future work in improvement of capture techniques.

E. Bait-holding equipment is primitive and work is being done to lessen mortality rates in the live bait tanks. The forced circulation type of bait tank, if properly designed, is found to be superior in holding ability to the usual open flow type of tank used by many aku boats.

F. Pollution can be a definite threat to certain bait fishing grounds as demonstrated by the enclosed report of a survey made in Hilo Harbor in 1948.

PRELIMINARY REPORT

SURVEY OF POLLUTION IN THE COASTAL WATERS OF KAUAI, T. H.

Beginning September 14 through September 19, 1949, a survey of the possible pollution of the coastal waters between McBryde Sugar Plantation and Kekaha Sugar Plantation on the leeward coast of Kauai was conducted by the research staff of the Division of Fish and Game, Board of Agriculture and Forestry. The purpose of this survey, which was undertaken at the request of the fishermen on Kauai, was to determine the extent of pollution in these waters and if possible the effect of the pollutants upon the inshore fisheries. Fish such as akule, opelu, kumu, weke, moana, uu, awaowao, aholehole, manini, etc., which make up the inshore fishery in these waters, are intimately dependent upon the shallow ocean bottom as well as upon the minute suspended planktonic organisms which make up their food. These fish are adapted to life in inshore waters where the conditions of their natural habitat are not subjected to extreme changes in food supply, oxygen tension, salinity and other hydrographic conditions. Any decrease in the abundance of fish in these waters is quickly attributed by the fishermen to these changes or to the presence of waste products from shore. Suspicion was directed toward the large volume of mud-saturated water which blanketed a great portion of these coastal waters and also to the great amount of bagasse and cane strippings which floated in these waters.

The work included visits to the McBryde, Olokele, and Kekaha Sugar plantations to survey the sources of the pollutants, oceanographic samplings to determine the chemical and physical condition of these waters,

plankton tows to determine the relative distribution of the minute marine organisms, dredging of the ocean bottom at various depths to observe the effect of the sediment upon the bottom fauna.

All three plantations visited had similar methods of excess mill water disposal — all muddy mill water was washed out to sea, including mud that had settled out. In one of the sugar mills, some attempt was made to settle out the mud and truck it back to the fields. This process, however, did not seem very successful in that cane strippings and muddy water still seem to continuously flow out to sea. In two of the plantations bagasse was dumped on the sea shore which is readily accessible to wave action. Some attempt was made to burn the bagasse but a great portion was seen to be washed out to sea (Plate I, II, III). The major pollutants observed in all three plantations were mud silt from sugar mill and irrigation ditches, cane trash and strippings, and bagasse (cane pulp).

Oceanographic samplings included 31 secchi disk readings, and 28 chlorinity and oxygen samples. The 16 dredge haul samples were tested for hydrogen sulfide and arsenic.

The secchi disk readings show that there is a constant shift of muddy water depending upon the physical condition of the sea -- wind force and direction, current and other hydrographic conditions. Day to day observations revealed this shift of the muddy water was to the southwest in the direction of the prevailing northeast trade winds. However, there was a general area southwest of the plantations where the coastal waters were always muddy. (Darkened areas on the Chart at the end of the report show the muddy water areas based on secchi disk readings and land

and air observations.)

As expected, the results of the chlorinity tests showed no significant changes in salinity with depth or with distance from shore. This was probably due to the relatively small volume of fresh water entering the sea with the pollutents and to the even, unaltered nature of the coastline which kept the water sufficiently stirred and mixed to give a rather uniform marine condition. Tests for arsenic and hydrogen sulfide in water samples and dredge haul samples gave negative or non-significant results.

The results of the oxygen analyses (by the standard Winkler method) presented different conditions. They showed extreme variations in the oxygen concentration, some of which were so low as to make it difficult to sustain any of the larger marine forms. Surface samples of muddy water areas showed a lower oxygen concentration than clear water areas. This was probably due to the greater organic decomposition using up the oxygen in these muddy water areas. Table below gives the sampling stations (correlated with numbers on chart) and the oxygen concentration in milliliters per liter of sea water.

Surface Water	Sampling Station	Surface O_2 Conc.	Middle Depth (ft.)	Middle O_2 Conc.	Bottom Depth (ft.)	Bottom O_2 Conc.
Muddy	1	2.71			20	3.81
Muddy	8	1.71			30	4.54
Muddy	15	0.70			70	4.21
Green	11	3.74	20	2.75	40	2.67
Clear Blue	4	4.63			70	4.58
Clear Blue	12	4.67	70	2.45	150	3.67

Note: 4.65 ml. of oxygen per liter of sea water is approximately average concentration of oxygen in open sea in this area.

The variation in oxygen concentration at the various depths and areas tends to indicate that when the muddy waters first enter the sea, it tends to form a layer at the surface. Gradually as more mixing with the salt water occurs forming a uniform saline condition, the heavier mud and silt settles to the bottom. The observations and results of the survey are not inconsistent with this picture, however, no definite conclusion can be drawn without further study.

Results of the surface plankton hauls indicated an appreciable decrease of planktonic organisms in the muddy water as compared with similar clear water areas. However, due to the lack of quantitative sampling equipment, this must be taken as an observation of qualitative samples.

Dredging gave a more definite picture of conditions on the bottom. The results of the dredge hauls are given below in the order of depth. The numbers in the first column indicate the sampling stations where the dredge hauls were made (see chart).

Sampling Station	Depth in feet	Condition of Bottom
1	20	Coral - living lots of life
3	30	"
8	30	"
2	35	"
11	40	"
10	55	Coral - few living covered with film of silt
15	65	"
4	70	"
13	90	*Clean sand
16	95	Mud containing few shells
6	115	Thick mud
9	125	"
14	150	"
7	160	"
12	160	"
5	180	"

*This station was outside the limits of sedimentation, thus, no mud settled on the bottom.

As the table above indicates there is no sediment settling out on the bottom at depths down to approximately 40 feet. Here, life on the bottom is vigorous and apparently normal. This is probably due to the wave action which is sufficient to prevent any sedimentation from taking place. Most of the coral between the depths of 45 and 70 feet were dead and were covered with a thin film of silt. The decrease in wave action at these depths resulted in the gradual settling out of the silt causing the slow death of the coral and other bottom sessile organisms. Beyond 90 feet to the greatest depth dredged (180 feet), the mud had settled out sufficiently to prevent any of the original bottom fauna to survive.

CONCLUSION: The effect of pollutants in these coastal waters are difficult to determine quantitatively. The extent of the so-called polluted areas depends upon the physical conditions of the sea and vary from time to time. Most of the fish comprising the present inshore fishery would probably avoid areas of low oxygen concentration as well as those areas containing large quantities of muddy water and cane trash. This would also be probably true for planktonic forms. It is quite conceivable, however, that some scavenger or carnivorous fish would gather at the fringes of these areas and feed on the food washed in from land.

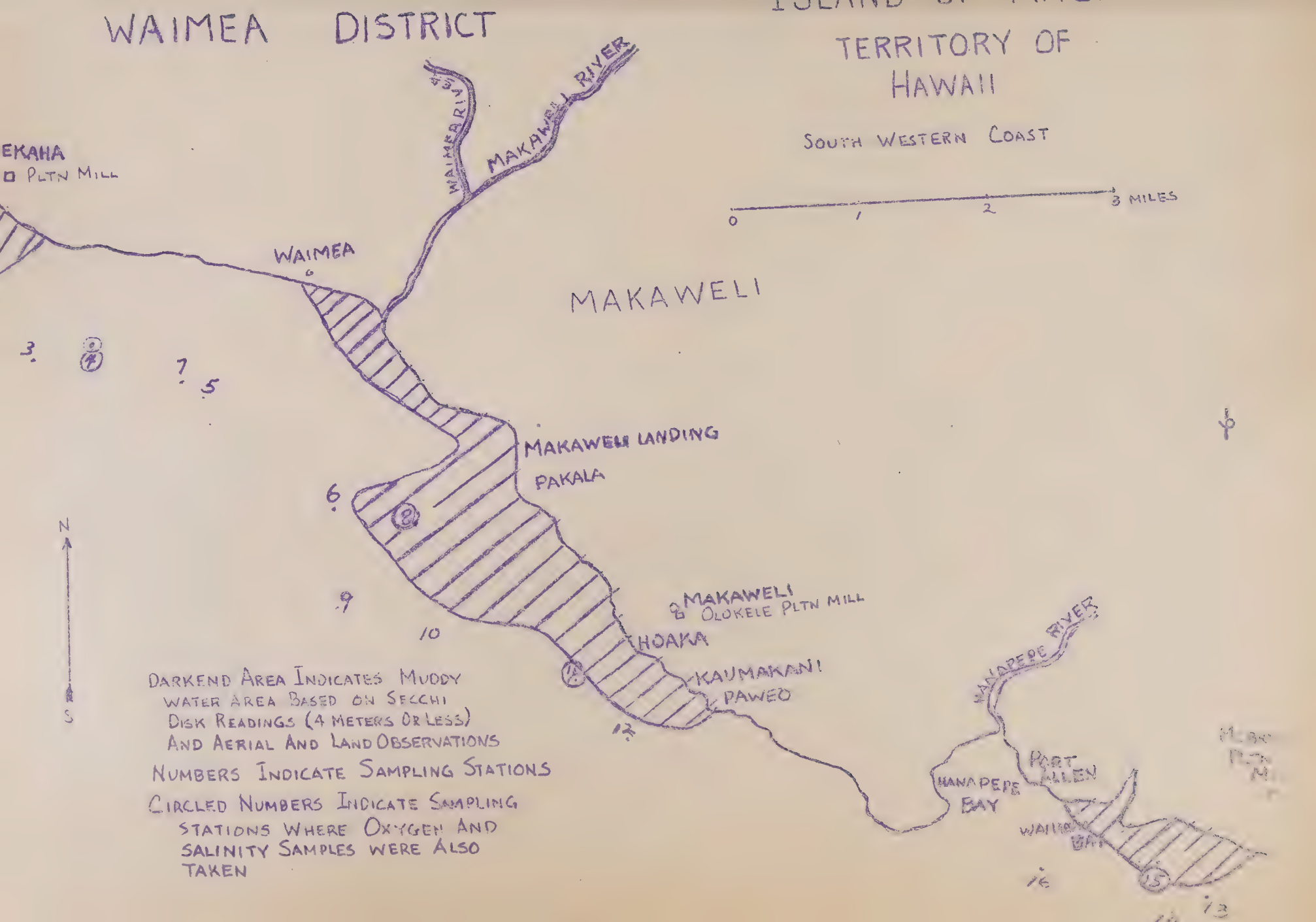
The effect of the pollutants upon the bottom is somewhat more definite. If the present method of sugar cane waste disposal is continued, coral and other bottom fauna in these areas between the depths of 45 and 75 feet will gradually die out. Bottom feeding forms such as weke, moana, kumu, manini, kala, etc., will have none of the usual food available. Bottom dwelling forms such as aweoweo, uu, aholehole, uhu, etc., will have to move to areas which sustain more life. Mud covered bottoms beyond 75 feet will not be

able to sustain most of the fish that comprises the present inshore fishery. Little can be said for the total quantitative effect of the pollutants by the present survey. More work will have to be done before any conclusive statement can be made.

WAIMEA DISTRICT

TERRITORY OF HAWAII

SOUTH WESTERN COAST



DARKEND AREA INDICATES MUDDY WATER AREA BASED ON SECCHI DISK READINGS (4 METERS OR LESS) AND AERIAL AND LAND OBSERVATIONS

NUMBERS INDICATE SAMPLING STATIONS

CIRCLED NUMBERS INDICATE SAMPLING STATIONS WHERE OXYGEN AND SALINITY SAMPLES WERE ALSO TAKEN

Fisheries Progress Report I, No. 2, Dec. 1, 1949

A PRELIMINARY STUDY OF FOOD AND FEEDING HABITS OF HAWAIIAN KAMAKA, MAHIMAHI, ONO, AKU AND AHI

by J. P. Welsh

Introduction

For the past year and a half, the Division of Fish and Game has been making a survey of the feeding habits and foods of the economically important pelagic (off-shore) fish around the Hawaiian Islands. This survey has been part of an overall study of these fish in a number of areas in the Pacific to determine what factors affect their lives and migratory habits. This food study is designed to determine what effect the locally produced food has in the distribution of these fish. In order to determine the effects of the availability of food on the various migrations of these fish, it is first necessary to determine just what animals are eaten. This study is primarily concerned with the determination of the various food-animals and also to determine the comparative importance of these food-animals as a source of food to the fish. Secondary studies are made on what indications the food eaten may give of the habitat, or living place, of these important commercial fish.

Five species of fish have thus far been studied in the course of the work already completed. These fish are very important to the Hawaiian fishery and constitute a major part of the tonnage of fish landed. The fish investigated are Kamaka or oceanic skipjack (Katsuwonus pelamis), Ahi or yellowfin tuna (Neothunnus macropterus), Ono or wahoo (Acanthocybium solandri), Kawakawa or oceanic bonito (Euthynnus yaito), and Mahimahi or dolphin (Coryphaena hippurus).

METHOD OF INVESTIGATION

The majority of the work on these fish has been done around the Island

of Oahu with fragmentary information coming from areas around Kauai, Hawaii, and Molokai (operating from Honolulu bases). The Oahu area was chosen because it was within easy range of the small boats used in collecting field data and it was also convenient to our Honolulu based boats and crews. Much of this area is also used by local fishermen and thus the fish collected were representative of the conditions of feeding to be found on the actual active Hawaiian fishery grounds. Material collected on the scientific boats could also be quickly and easily transported to a laboratory in Honolulu where the analysis of food took place. With the boats operating close to a base such as Honolulu where fuel, equipment and repairs could be easily obtained, it was found that much more work could be accomplished in a short-er time and with much less effort.

Three different methods were used to collect the necessary fish stomachs and analysis in this study. Naturally, the first method tried was to collect stomachs of fish landed as part of the commercial catch in Honolulu. Aku was used from the local tuna cannery and some attempt was made to gather stomachs of other fish at the local markets. As the analysis of this cannery material progressed, it was found that the fish available were not fresh enough to give any positive results. Evidently, the digestion in a fish stomach is very rapid and by the time the fish are landed in Honolulu, most of the food-animals in the fish stomachs were just so much unidentifiable gurry. The small fish in the stomachs were unrecognizable in almost all stomachs, but some hard-shelled crustaceans were still in fair shape. However, small nehu used as live-bait to catch the aku were mixed with the "natural" food of the tuna. As all of the small fish in the tuna stomachs were indistinguishable, there was no way to determine natural from unnatural food. As this study is supposed to determine <u>what</u> the food-animals are and just what <u>proportion</u> of the total food used by the fish these animals constitute, the market-sampling method was found to be unsatisfactory. The individual animals just could

not be identified. An additional difficulty arose in that there was a reluctance expressed by the local fishermen in having the stomachs removed from landed fish because this lowered the value for marketing. Consequently, very few fish other than cannery aku were available for this study from locally landed fish*.

The next method tried was to send a biologist out with the aku fishing boats so he could sample the fish while they were extremely fresh. It was found that the working conditions were almost impossible on the boats in any kind of rough sea and here again there was a certain opposition to the necessary cutting of the fish. However, some good material was collected by analysing the food that was spit-out on the decks of the sampans by the aku when they were landed. These specimens were very fresh and easily identifiable, but their relationship as to relative importance as a food due to their total volume in the stomach could not be measured by this method. The collection of data tended to be rather spotty and much time was wasted by a highly trained biologist just riding around the ocean waiting for the fish to be caught.

The final and most satisfactory method used was to utilize territorial research vessels catching all five different species of fish by simple trolling and live-bait methods. It was the policy that wherever the research vessels went they always trolled and in this manner a considerable amount of fish stomach material was collected. There was adequate space on the

*Later work has indicated that fish taken by flagline methods and held in ice until they were marketed proved quite satisfactory for stomach analysis. Analysis of these flagline fish has given us much information about very large Yellowfin tuna (Neothunnus macropterus) and large Bigeye tuna (Parathunnus sibi). This analysis of large(100-300 lbs) ahi which is presently being carried out indicates that a change in feeding habits seems to occur in the larger ahi as compared with the small ahi (7-15 lbs) discussed in this paper.

research vessel to carry all the necessary equipment and preservatives to assure a correct procedure of analysis. This was much in contrast with the method of sending a biologist out on the aku boats when it worked a hardship on the fishing crews to have the equipment and extra personnel getting in the way of normal fishing operations. Also, on the scientific boats it was possible to experiment with various types of bait in catching the fish. This helped to determine what factors influence the type of food which is preferred by the fish and it also enabled an observation of the actual feeding reactions. Of special interest here was an observation that migrating schools of aku seemed to generally refuse trolled bait of any kind. During the summer months -- June, July and August, 1948, approximately 14 "breaking" tuna schools were fish by trolling. Only 3 of these schools produced strikes and even these strikes were from very few fish. It was only possible, by using the research vessels, to fish and collect stomachs in areas where the work was needed. Exact locations and depths of caught fish could easily be recorded and the research vessels were able to operate at a range from shore which exceeded the normal range of th local fishing boats. It was possible at any time to use bulky scientific collecting gear such as a night light or plankton nets to sample in any area the type of feed present. Electronic sounding equipment and bathythermographs gave the research staff exact information of the depth and temperature of the water from which the fish were caught.

SUMMARY OF ANALYSIS

A summary of the results of the study thus far is best represented in a tabular form*. The study should be divided into two parts for clarity at

*For complete summary of analysis, see appendix.

these two parts are incorporated into a final general summary. The first part includes the study of aku stomach contents taken at the local tuna cannery. All of these fish were caught by the Hawaiian aku fleet.

Table I

Aku Stomach Analysis of Cannery Fish

Number of cannery aku stomachs analysed: 200

Percentage of identifiable material in cannery aku:

1. Identified material 52.8%
2. Unidentified gurry 47.2%

Major categories of food animals

1. Fish 63.4% by number and volume

Breakdown of identified fish:

	Percentage	Adult Habitat	actual % of total
·Pomfrets (Bramidae)	39.5	Offshore	24.9
·Opelu, Akule (Carangidae)	26.2	"	16.5
·Malolo (Exocoetidae)	10.4	"	6.5
·Lizard fish (Synodontidae)	8.7	Inshore	5.5
·Surmullets (Mullidae)	7.5	"	4.7
·Butterfly fish (Chaetodontidae)	2.8	"	1.8
·Nunu (Aulostomidae)	2.0	"	1.3
·Squirrel fish (Holocentridae)	0.8	"	.5
·Humuhumu (Balistidae)	0.7	"	.4
·Cowfish (Ostraciidae)	0.6	"	.4
·Seahorse (Syngnathidae)	0.6	"	.4
·Gurnard (Triglidae)	0.2	Offshore	.1

2. Squid and Octopi 27.8% by number and volume

Breakdown of Cephalopods:

·Muhee	99.2	Offshore
·Hee	0.8	Inshore

3. Crustacea 8.8% by number and volume

Breakdown of identified Crustacea:

·Lysiosquilla maculata	81.8	Inshore
·Odontodactylus	17.2	"
·Crab larvae	0.4	"

Table 2

ESTIMATION OF RELATIVE IMPORTANCE OF AVAILABILITY OF FOOD USED BY AKU

The following is a list of the food categories given in the order of their importance of availability to the aku. The value here is determined by the amount of use each food is given by the aku , in other words, the number of stomachs in which the food was found.

Food	Number of Stomachs in which found
Muhee (decapod mollusc)	35
Lysiosquilla maculata (stomatopod)	30
Odontodactylus (Stomatopod)	33
Opelu, Akule (Carangidae)	2
Lizard fish (Synodontidae)	5
Pomfrets (Bramidae)	1
Malolo (Exocoetidae)	2
Surmullets (Mullidae)	1
Nunu (Aulostomalidae)	3
Butterfly fish (Chaetodontidae)	2
Hee (Octopod mollusc)	3
Seahorse (Syngnathidae)	3
U'u (Holocentridae)	2
Humuhumu (Balistae)	2
Crab larvae (Megalops brachyuroid larvae)	5
Cowfish (Ostraciidae) (Ostracionidae)	1

In addition to the food-animals listed above, a considerable number of food-animals were spit out on deck by the aku. These specimens were preserved and later identified. This list gives us an idea of additional kinds of food-animals utilized by the aku but their relative importance to other kinds of food is unknown due to the inability to compare their individual bulk and numbers with the total bulk and number of individuals of the food content of each individual aku stomach. The list of these specimens is given below:

Table 3

·Seahorse (Hippocompus kuda)
·Akule (Selar crumenophthalmus)
·Trunkfish or Cowfish (Lactoria fornasina)
·Butterfly fish (Chaetodontidae)
·File fish (Monocanthidae)
·Humuhumu (Balistidae)
·Moana (Mullidae)
·U'u (Holocentridae)
·Cardinal fish (Apogon idae)
·Lizard fish (Synodotidae)
·Manini (Hepatus triostagus)
·Aweoweo (Priacanthidae)
·Hauliuli (Gempylidae)
·Malolo (Exocoetidae)
·Small Aku or Kawakawa (Katsuwonidae)
·Butter Fish (Centrolophidae)
·Piha (Spratelloides delicatulus)

Several kinds of invertebrate food-animals were also collected on sampan decks and identified. These animals were usually muhee (decapods), young aloalo (Stomatopods), crab larvae (Megalops brachyuroid larvae), and hee (Octopods).

The above analysis of the stomach contents of aku sampled at the local cannery shows a high degree of unidentified material - almost one-half of all analysed material. This is undoubtedly due to the rapidity of digestion in the stomachs which occurs even though the fish has been killed. Such a high degree of unidentified material leaves a very large hole in any quantitative calculations of the most important type of food-animals. These calculations can usually only be made on a comparative basis -- comparing the individual kinds of animals to the total food volume and balancing this comparison with availability (represented by the number of aku stomachs in which each individual food animal was found). As the added factor of bait used to catch the fish is also present, it is impossible to estimate what proportion of the unidentified gurry is artificially introduced food (bait) and what part of it

is natural food. It is even generally impossible to determine whether a great deal of the gurry is from vertebrate or invertebrate sources. The cannery study is generally helpful in determining some of the most common types of food-animals only on a qualitative rather than an quantitative basis.

The cause of this limitation was found to be due to the protracted length of time between the catching of the fish and the time when the fish stomach is available to analysis in the cannery.

FIELD ANALYSIS OF FRESH FISH

Below is given the analysis of stomachs from the five species of fish being considered in this study. These fish were caught by the Territorial research vessels and the stomachs were immediately removed and preserved for later analysis. In this way, almost all of the material in the stomach was identifiable and it was possible to get accurate measurements of the bulk and number of each individual food used by the fish. Also, it was possible to get an exact location, time of capture, estimated time of greatest feeding activity, observations of peculiarities of feeding, and other factors which may point to a significant characteristic of the feeding reactions of any of the five fish being studied. The analysis of the data collected by the research vessel from the five species being studied - Kawakawa, Ono, Aku, Ahi and Mahimahi - are discussed separately below.

Relative Importance of Foods used by the Kawakawa

The percentage rating given at the right below is an average of the per cent of the total bulk of the individual food used (indicating food-value), the total number of individual food-animals used (indicating abundance), and the total number of stomachs in which the individual food were found indicating availability.

Table 4

SPECIFIC INDIVIDUAL FOODS	COMPARATIVE AVERAGE PERCENTAGE RATING BY NUMBER AND VOLUME
Megalops brachyuroid larvae (young crabs)	35.76%
Lysiosquilla maculata larvae (young alcalo)	27.97
Unidentified partly digested fish	7.49
Decapterus pennulatus (opelu)	2.89
Thunnidae (tuna)	2.30
Gurry and parts of fish	2.12
Pennaeus marginatus (Opai)	1.97
Unidentified squid (muhee)	1.92
Ommastrephus hawaiiensis (Muhee)	0.56
Spratelloides delicatulus (Piha)	1.85
Promethichthys prometheus (rabbit fish)	1.24
Hippocampus kuda (seahorse)	1.00
Myctophidae (Lantern fish)	0.76
Monocanthidae (File fish)	0.75
Monocanthus spilosoma (File fish)	0.35
Monocanthus melanocephalus (File fish)	0.34
Catherinnes (File fish)	0.28
Chelidonichthys kumu (Alolau)	0.73
Lactoria fornasini (Pahu)	0.65
Squilla oratoria (Alcalo keiki)	0.56
Tetradon meleagus (Puffer)	0.53
Belone platyura (ahaaha)	0.52
Pieces of crustaceans	0.51
Hemiramphidae (half-beaks)	0.46
Unidentified stomatopods (alcalo)	0.44
Ranzania truncata (Makua)	0.40
Holocanthus (squirrel fish)	0.36
Tetradon hispidus (Puffer)	0.53
Gonodactylus stomatopod (alcalo)	0 26
Stenophus hispidus (Bandana shrimp)	0.22
Collybus drachme (Pomfret)	0.22
Pomacentridae (Damsel fish)	0.20
Fistularia petimba (Nunu)	0.17
Petroscirtes ewaensis	0.12
Tropidinus zonatus (Ukiki)	0.12
Clupiidae (sardine)	0.12
Pseudosquilla stomatopod larvae (alcalo)	0.11
Parabacceus antarcticus (slipper lobster)	0.11
Pleuronectydae (Flatfish)	0.10
Myctophus andrae (Lantern fish)	0.09
Cirolana (isopod)	0.09
Unidentified shrimp (opai)	0.08
Pennaeidae (opai)	0.08
Tremoctopus violaciens (hee)	0.08
Aulostomatidae (nunu)	0.08
Gobiidae (rock jumpers)	0.08
Lactoria cubicus (trunk fish)	0.08

AVERAGE RATING OF GENERAL FOOD BY PER CENT	AVERAGE PERCENTAGE RATING* BY NUMBER AND VOLUME
Crustacea	70.41%
Fish	27.07%
Squid	2.53%

From the above analysis it is evident that the Kawakawa seems to prefer to feed on small crustacea, most of which have the reef as their adult home but which spend the young period of their life floating or swimming freely in the open sea. It is interesting to note that the majority of the fish caught in this study were taken within a 9-mile distance from shallow water even though fishing operations were carried out at much greater distances from the nearest shallow water. No kawakawa were taken at a greater distance than 9 miles from water that measured less than 300 feet in depth. The above fact, coupled with the fact that the majority of the food used by the Kawakawa was generally of a shallow water variety, tends to point to the waters in the immediate vicinity of the reefs or banks as the preferred habitat and feeding grounds of the Kawakawa. Although the Kawakawa of a larger size will occasionally eat a large, fast-moving food-animal, it seems likely, from the above analysis, that the small, slower-moving animals are the mainstay of the Kawakawa diet. It might be said that the reefs play a fairly essential part in providing a rather large source of food for the Kawakawa. The scarcity of squid and deep-sea fish in the diet of the Kawakawa seems to show that the Kawakawa probably has a

*This rating is determined by multiplying the number of food animals times the mass of food the animals provide times the number of stomach in which the food animals appear and comparing this value with the two other major food catagories on a percentage basis.

tendency to feed near the surface or in very shallow water near shore. The presence of almost adult stomatopods, clams, slipper lobsters and adult bethonic fish seems to show that the Kawakawa may even feed near or at the actual rocks of the reef. The detailed Kawakawa stomach analysis may be found in the appendix of this report.

Kawakawa Stomach Analysis

Table 5

Total number of Kawakawa analized	261
Total number of empty Kawakawa	65
All Kawakawa analysed were caught by trolling methods.	
Number of food animals per Kawakawa	15.433
cc. of food per Kawakawa	6.608 cc.
Average volume per food animal used by Kawakawa	0.428 cc.

FISH: 27.07%

Per cent total number of fish used by Kawakawa	7.22%
Per cent total volume of food in cc.	39.79%

CRUSTACEA: 70.41%

Per cent total number of crustacea used by Kawakawa	92.03%
Per cent total volume in cc.	57.33%

CEPHALOPODS: 2.53%

Per cent total number of cephalopods used by Kawakawa	0.745%
Per cent total volume of food in cc.	2.864%

Relative Importance of Food Used By Mahimahi

Percentage rating is an average of the per cent of the total bulk of the individual food used (indicating food value), the total number of individual food animals used (indicating abundance), and the total number of stomachs in which the individual foods were found (indicating availability).

Table 6

SPECIFIC INDIVIDUAL FOODS		COMPARATIVE AVERAGE PERCENTAGE RATING BY NUMBER AND VOLUME	
Parexocoetus brachypterus	Malolo	18.61	30.05%
Exocoetus volitans	Malolo	5.23	
Unidentified Exocoetidae	Malolo	4.73	
Cypsilurus simus	Malolo	1.93	
Spratelloides delicatulus (Piha)		12.10	
Unidentified partly digested fish		11.29	
Penneaus marginatus (Opai)		8.10	
Lysiosquilla maculata (young Aloalo)		6.66	
Fish gurry		5.15	
Ablennes hians (Ahaaha)		4.86	
Decapterus pennulatus (Opelu)		3.75	
Belone platyura (Iheihe)		3.23	
Lactoria fornasini (Pahu)		1.75	
Unidentified shrimp (Opai)		1.41	
Unidentified squid (Muhee)		1.49	
Ommastrephus hawaiiensis (Muhee)		0.25	
Monocanthidae (Triggerfish)		1.16	
Monocanthus spilosoma (Triggerfish)		0.77	
Catherines sandwichensis		0.43	
Extremeus micropus (Mikiawa)		0.43	
Unidentified Scombridae (Aku, Kawakawa, Ahi)		1.07	
Megalops brachyuroid larvae (young crab)		0.98	
Chelidonichthys kumu (loloau)		0.86	
Hippocampus kuda (seahorse)		0.85	
Hemiramphidae (half-beaks)		0.85	
Synodotus sp. larvae (young ulae)		0.83	
Ranzania truncata (Makua)		0.61	
Lactoria disphanus (trunk fish)		0.53	
Holocentridae (Squirrel fish)		0.46	
Pieces of opai, aloalo and opaiula		0.41	
Pomacentridae (damsel fish)		0.33	

Average General Food Rating	Comparative General Rating
Fish	81.78
Crustacea	14.41
Squid	1.82

From the above analysis there seems to be evidence that the mahimahi feeds very heavily upon the malolo with a secondary preference for other fish found near the surface of the sea. The noticeable lack in use of

squid coupled with the very high use of surface fish such as the malolo and piha seems to indicate the surface waters of the open sea at any distance from the nearest land as the preferrable habitat of the mahimahi and the area in which it probably does the majority of its feeding. The showing of crustacea in the analysis was due mostly from the examination of small mahimahi which were caught very near to shore or shallowreef areas. The mahimahi seems to greatly reduce its feeding upon the large crustaceans when they reach a length approaching 950 mm. (about 3 feet, 3 inches long). The large amount of food usually found in each mahimahi stomach seems to indicate that fish is a rather active and voracious feeder which prefers large prey of a fast-moving nature. It was found that as the distance from shore became greater, the mahimahi seemed to depend more and more upon the malolo as the greatest source of food. However, the malolo used by the mahimahi at great distances from shore was a different species from the malolo used by mahimahi feeding fairly close to land. It was found that many reefliving fish were carried far out to sea by the current when these reef-fish gathered around logs for protection as these logs drifted a short distance from shore before passing seaward again.* Due to this condition, it is possible to find some reef-living fish in the stomachs of mahimahi which were caught scores of miles at sea but were near floating logs when caught. (A certain amount of collecting was carried out at distances ranging to 120 miles from shore). We found no tendency for the numbers of mahimahi to decrease as the distance was increased from the nearest land, in fact a slight increase

*The following fish were captured around a floating log 38 miles off the island of Kauai, April 2, 1949

2 Hepatus triostegus (manini) Reef fish
5 Hepatus fuliginosus (black tang) Reef fish
1 Naucrates ductor (pilot fish) Non-reef fish
1 Amia sp. (cardinal fish) Reef fish
3 Vitraria clarescens (Goby) Reef fish
7 Selarias sp. (blenny) Reef fish

in catch from trolling was noted. All fish taken far from shore had full stomachs - the food consisting mostly of the off-shore type of malolo. This might indicate a lack of dependence by the mahimahi upon reef-produced food. Another possibility is that the numbers of mahimahi were less at greater distances from shore but the lack of such tremendous amounts of food such as is available to "inshore mahimahi" would make the "offshore mahimahi" more willing to strike a lure; hence the slightly increased catch in waters farther from shore.

Mahimahi Stomach Analysis

Table 7

Total number of mahimahi analysed	58
Total number of empty fish	0
All fish were caught by trolling methods.	
Number of food animals per mahimahi	6.9
cc. of food per mahimahi	96.5 cc.
Average cc. per food animal	13.6 cc.
FISH: 81.78%	
Per cent total number of food animals	64.75%
Per cent total volume of food	97.147%
CRUSTACEA: 14.41%	
Per cent total number of food animals	33.25%
Per cent volume of food	2.301%
CEPHALOPODS: 1.82%	
Per cent total number of food animals	2.0%
Per cent total volume of food	0.552%

Relative Importance of Foods Used by Ahi

Percentage rating is average of total per cent of total number of food animals used, total bulk of food used, and the total number of stomachs in which the food was found.

Table 8

SPECIFIC INDIVIDUAL FOODS	COMPARATIVE AVERAGE PERCENTAGE RATING
Lysiosquilla maculata (aloalo)	18.73%
Unidentified squid	16.73
Ommastrephus hawaiiensis	9.67
Collybus drachme (Pomfret)	12.31
Megalops brachyuroid larvae (young crab)	9.30
Odontodactylus hansenii	8.53
Chelidonichthys kumu (Loloau)	6.26
Unidentified fish	5.87
gurry (digested material in stomach)	2.01
pieces of unidentified fish	2.82
Decapterus pennulatus (Opelu)	1.89
Belone platyura (Iheihe)	1.27
Ostraciidae (Pahu)	1.19
Strolophorus shrimp (Opaiula)	1.00
Hippocampus kuda (seahorse)	0.83
Penaeus marginatus (Opai)	0.80
Tremoctopus violacens (Hee)	0.80

AVERAGE GENERAL FOODS RATING	COMPARATIVE AVERAGE PERCENTAGE RATING
Crustacea	38.41%
Fish	31.74
Squid	27.28

The stomach analysis of the ahi as compared with the stomach analysis of the other four species of fish being studied shows a marked increase over the other 4 species in the use of squid as a major source of food. The ahi analysed were the same size and were caught in the same area and at the same time as representatives of the four other species of fish under investigation in this paper. Hence a preference for squid might possibly be indicated by this increased use by the ahi. More work must necessarily be done in

order to reach a definite conclusion in this assumption. Another possible explanation for the increased use of squid may be a matter of the squid sharing common habitat over a greater length of time with the ahi than with the other four species of fish being studied. The temptation to assume a relationship of this is strong in the case of the mahimahi and maloʻo which have been previously discussed. If the second assumption of a shared habitat is considered, then an interesting problem of what this habitat might be can be discussed.

The squid most commonly used by the ahi is Ommastrephus hawaiiensis. This squid has certain habits (such as its observed repellance to strong artificial light during night-lighting operations and lack of observable occurance near the surface of the sea during daylight hours, but a common occurance on the surface of the sea during the hours of darkness and certain structural modifications (photophores or light-producing organs) that might indicate a preference for a dark habitat. In the hours of darkness this habit would include surface waters but daylight would tend to put this semi-dark habitat at considerable depth below the surface of the sea. Another indication of a diurnal migration of squid is the practice of the flagline fishermen setting the lines only after daybreak. If the lines are set in the darkness before daybreak, the squid eats a majority of the bait, but if the lines are set after daybreak, the loss of bait to squid is negligable. The bait is usually set to a depth of 180-240 feet - well above a depth of semi-darkness. The observable reactions and especially modified organs of the squid listed above seems to indicate a diurnal squid migration which is directly concerned with the squid's preference for a certain low intensity of light. The ahi may follow such a

possible diurnal migration if it tends to share a fairly common habitat with the squid. There is a possibility that the ahi might not descent to the semi-dark habitat after the squid but carry out the majority of its squid-feeding in surface waters at night when the squid are abundant at this level. One objection to this theory might be raised on the ground of the rapidity of digestion in the tuna stomach when considered in light of the softness and digestibility of squid. Previous observations upon the rate of digestion of the soft-bodied fish, piha (Spratelloides delicatulus), by the aku (Katsuwonus pelamis) indicates an extremely rapid digestive rate to the point where the individual food-animal in the stomach is unrecognizable in less than one hour.* As all of the ahi examined were caught some hours after daybreak it is not likely that a squid eaten several hours previously during the hours of darkness could still be in as good shape as the squid removed from the ahi stomachs that were analysed. However, some squid were in such a state of digestion that might indicate they were taken by the ahi such a lenght of time previously to put time of capture in the hours of darkness. There is a slight indication here that the ahi may well feed at the surface to a greater extend during the hours of darkness and experimental fishing to test this possibility is recommended. Another indication that the ahi may spend a greater time at some depth rather than at the surface of the sea during the daylight hours is the comparative success of the fishing methods for this fish. Small ahi (immature) and an extremely small number of large, mature ahi are taken at the surface of the sea and fairly close to shore by simple trolling methods. The ahi taken at the surface by trolling are all of the

*See section on Aku in this paper.

surface by trolling are all of the species Neothunnus macropterus or yellowfin tuna and no Parathunnus sibi or big-eyed tuna are taken. However, flagline fishing takes both species of ahi in considerable numbers. These flaglines fish at a depth approaching a light intensity much less bright than at the surface and, of course, much closer to the thermocline--that depth in the sea where wind-currents have caused a sharp change in the temperature and salinity of the water from surrounding water conditions. Much work needs to be done in finding the effect of the thermocline in providing a habitat that would be chosen as preferable by the ahi.

All of the ahi examined in this study were caught fairly close to the reef; hence the high rating of reef-dependent animals such as young crabs and aloalo (stomatopods). The size of the individual food-animals and the amount of food used by the ahi might indicate that it is a rather voracious fish which tends to feed on fairly large, faster-moving animals of a pelagic habitat in the stage of life in which they were captured. The high rating of the crustacea above is probably due mostly to the abundance of these animals in the area in which the ahi were caught.* However, the small crustacea provide very little bulk to the ahi diet and hence are of much smaller food-importance to the ahi than the bulk - providing fish and squid.

Table 9

Ahi Stomach Analysis

Total number of ahi analysed	20
Total number of empty ahi	2

*¼-½ mile off the island of Moku Manu on windward Oahu.

FISH: 31.74%

Per cent total food animals	20.90%
Per cent total food mass	47.4%

CRUSTACEA: 38.41%

Per cent total food animals	63.63%
Per cent total food mass	9.3%

CEPHALOPODS: 27.28%

Per cent total food animals	15.45%
Per cent total food mass	43.3%

Average number of food animals per ahi - - -	11.0
Average mass per food animal - - - - - - -	3.138c.c.
Average total mass of food per ahi - - - -	34.525 c.c.

Relative Importance of Foods Used by Aku

Percentage rating is average of total per cent of total number of food animals used, total bulk of food used, and total number of stomachs in which the food was found.

Table 10

SPECIFIC INDIVIDUAL FOODS:	AVERAGE PERCENTAGE RATING
Unidentified fish	28.66%
Unidentified squid	25.98
Megalops brachyuroid larvae (young crab)	11.55
Odontodactylus hansenii (young Opailolo)	11.04
Lysiosquilla maculata (young Aloalo)	4.71
Young fish just hatched	6.47
Fish gurry	4.17
Amia erythrina (Upapalu)	2.63
Synodotus sp. (Ulae)	1.69
Bramidae (Pomfret)	1.56
Parts of Opai, Aloalo and Opailolo	1.42
*Lutianidae (Snappers)	1.25
**Pomacentridae (Damsel fish)	1.05

*The Lutianidae include such Hawaiian fishes as Uku, Ulaula, Opakapaka, and Ukiki.

**The Pomacentridae include such Hawaiian fish as Aloiloi, paapaa, & Maomao.

General Foods

Fish	50.82%
Crustacea	27.09%
Squid	21.69%

From the above analysis, it is probable that aku depend a great deal upon small fish for the bulk of their food. However, it is noticeable in this species that the aku uses a much more varied diet than the other fish studied in this analysis. The rather high rating of the small opai (shrimp and crabs) which drift out from the reef into deep water seems to indicate that the aku depends to a fair degree upon certain food which are reef-living in their adult forms but which live swimming or drifting in the open sea during the early part of their life. All of the aku examined were caught fairly near the reef- hence a high number of reef-living crustacea is to be expected. The high rating of squid might indicate a tendency for the aku to feed at some depth during a part of the day as was discussed above in the case of the ahi. Observations were possible to determine some idea of the digestive rate of this fish. A number of aku were caught over a period of about one and one-half hours continuously. Throughout this time, the aku were fed numbers of a distinctive bait fish called piha (Spratelloides delicatulus). These fish are recognizable by distinctive mouth parts and hence can be identified even if the body is mutilated or partly digested. The stomachs of the aku were examined immediately after capture and it was found that all the piha remained recognizable during the first hour of fishing. Stomachs analysed during the second hour showed many unrecognizable fish in an advanced stage of digestion. Careful examination of the vertebrae and considering the size of these partly digested fish indicated they were piha. This observation might indicate a rapid digestive rate of aku which would

make animals found in good shape in the stomach recent in their capture by the aku.

Table 11

Aku Stomach Analysis

Total number of fish analysed - - - - - - - - - 24

Total number of empty fish - - - - - - - - - 3 (All caught trolling)

FISH: 50.82%

Per cent total food animals	37.41%
Per cent total food mass	71.858%

In aku caught by trolling methods, 9 food fish were found in the stomachs and supplied 13.1 cc of mass. In aku caught by bait methods, 43 food fish were found in the stomachs and suppled 139.8 c.c.

CRUSTACEA: 27.09%

Per cent total food animals	42.44%
Per cent total food mass	5.232%

12 trolling caught fish	32 food animals	6.8 cc
13 bait caught fish	27 " "	15.1 cc

CEPHALOPODS: 21.69%

Per cent total food animals	20.15%
Per cent total food mass	22.193%

(All from bait caught fish)

Relative Importance of Foods Used by Ono

Table 12

Percentage rating is average of percent of total bulk used, total number of food animals used, and total number of times the food was found in

individual fish stomachs.

SPECIFIC INDIVIDUALS	AVERAGE PERCENTAGE RATING
Katsuwonus pelamis (aku)	32.61
Unidentified squid (Muhee)	24.41
Decapterus pennulatus (opelu)	15.23
Fish gurry	10.71
Apogonidae (cardinal fish)	10.56
Ommastrephus hawaiiensis (muhee)	9.05

AVERAGE RATE OF GENERAL CATEGORIES	
Crustacea	none
Squid	33.46%
Fish	66.54%

From this analysis it is evident that the ono insofar as the few individuals examined indicate, depend upon rather large fish and large squid for the majority of their food. Due to the large number of empty stomachs noted in this analysis (10 out of 17) it may be said that the ono probably feeds only intermittently - not continuously - but when he feeds, the food used is of considerable volume and the individual food animal is of considerable size and is of an active nature. Although the ono examined in this study were caught very near reef areas where numerous crustacean animals live in abundance and are readily available as food, the ono shows no tendency to utilize this source of food. All of the fish identified in ono stomachs are pelagic in habitat. The above two facts would indicate that the ono may not depend directly upon the reef areas as a source of food. However, the small fish that the ono utilizes do feed on reef-animals, thus indirectly affecting the ono.

Table #3

Ono Stomach Analysis

Total number of Ono analysed - - - - - - - -	17
Total number of empty fish - - - - - - - -	10

FISH: 66.54%

Per cent total number food animals	46.154%
Per cent total food mass	91.933%
(All trolling caught fish)	

CRUSTACEA: 0.00%

CEPHALOPODS: 33.46%

Per cent total number food animals	53.846%
Per cent total food mass	8.067%
(All trolling caught fish)	

FOOD USE:

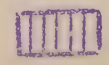
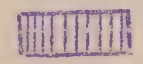
Average number of food animals per ono	00.765
Average c.c. of food per ono	39.029 c.c.
Average mass per food animals	51.037 c.c.

Given below are two tables showing in graphic form the relative importance of the three general categories of food (crustacea, cephalopods, and fish) used by the fish under investigation. These charts indicate the relative importance of the food items by two standards - number of individual food items available to the fish and bulk of food material provided by all the individual food animals in each of the three major food categories.

PER CENT TOTAL BULK

FOOD	ONO	AHI	AKU	KAWAKAWA	MAHIMAHI
CRUSTACEA	none				
SQUID					
FISH					

PER CENT TOTAL NUMBER OF FOOD ANIMALS USED

FOOD	ONO	AHI	AKU	KAWAKAWA	MAHIMAHI
CRUSTACEA	none				
SQUID					
FISH					

From the above analysis of the stomach content of the fish being studied, it is evident that small fish provide a major part of the food in bulk form. However, crustacea seem to provide a majority of the total number of individual animals used as food by these five fish.

Another fact which shows up in the analysis is the apparent differences of the food used by the five different species of fish being studied. It is shown that ahi and kawakawa seem to depend to a greater extend upon crustacea than the mahimahi, ono, or aku. Also, the ahi uses more squid and the mahimahi uses more malolo than the other fish. This could possibly be due to the individual species of fish having a preferable habitat in which the food animals occur in large numbers. The ahi uses squid to the greatest extent of the fish being studied, and the mahimahi is the heaviest user of malolo. The kawakawa depends a great deal upon small crustacea for the majority of its food. This is reflected in its living habits in that it is found that the kawakawa seldom venture more than 10 or 20 miles from a shallow reef. The crustacea used by the kawakawa are usually a kind that require a reef habitat at the adult period of their life but have a young period in their life when they drift or swim miles from shore and are easily captured by the kawakawa and other fish. Here the reef is of extreme importance as a source of <u>direct</u> food to the kawakawa.

As a summary, it may be said that the ahi is a pelagic-preferring fish which eats voraciously and prefers large fish and squid; the aku is more apt to be found near the surface and tends to use a more varied diet - feeding mostly on many varieties of fish as its major source of food and depending less upon the squid; the ono is probably a solitary fish which seems to prefer a pelagic habitat fairly near the surface and tends to feed

upon very large, fast moving fish - a favorite food being aku, around schools of which the ono isusually found; the kawakawa seems to prefer a semi-pelagic habitat fairly near to the shore or a shallow reef and prefers to feed upon the myriads of crustacea and small fish which originate from the reef and the mahimahi which prefers a habitat of a purely pelagic nature very near the surface of the sea and at no chosen distance from shore where it may feed voraciously upon its favorite food - the malolo.

The analysis that has been given of the stomach content of the fresh-caught fish is merely a first progress report of the trends which are appearing in the overall picture of the food habits of the five fish being studied.

Enough field data has now been collected to made a fairly complete analysis of the food and feeding habits of the Kawakawa and Mahimahi but more data must be collected from the stomachs of Aku, Ahi, and Ono. Also some attempt will be made to collect a number of stomachs from an area at a considerable distance from shore in order to compare the available food in this area with the food already collected from stomachs of fish caught in inshore waters. This is expected to give us an idea of the part the reef plays in supplying food animals to the five fish being studied at various distances from shore and to determine if these reef-animals have a tendency to draw the fish closer to the inshore waters where they come within reach of commercial fishing operations. The study of the reef-animals found in the stomachs will also allow us to determine which important food-animals are under the direct influence of man and what part man may have in affecting the abundance of this source of food.

It is hoped to find if the food found in the stomachs comes from areas or depths which are not now fished by commercial operations. If this is so, what is the best way to successfully fish these areas and depths?

Another problem to be analysed in this work is to try to determine the effect of spawning and moon-cycle upon the willingness of the fish to feed.

A TROLLING SURVEY OF HAWAIIAN WATERS

Division of Fish and Game
Fisheries Research Progress Report I, No. 4, Dec. 14, 1949

Board of Commissioners of Agriculture and Forestry
Honolulu, T. H.

A TROLLING SURVEY OF HAWAIIAN WATERS*

By James P. Welsh**

In the winter of 1947-48, several research projects were undertaken by the staff of the Fisheries Department of the Division of Fish and Game which required analysis of fish in a fresh and unhandled condition. One of these projects concerned a very careful measurement of the body proportions of the fish, hence it was important to obtain the fish for measurement before drying or handling could distort these body proportions. Another project concerned an analysis of the stomach content of various species of fish. Digestion is probably quite rapid in these fish and it has been found that this process continues even after the fish have been killed. The best results from stomach analysis work is obtained from the most recently captured fish. An inspection of the fish available in the local markets indicated that delay in arrival at the market, roughness of handling and drying tended to make market fish unsuitable for use in the projects outlined above. Due to the type of analysis used in these projects, it would have been necessary to purchase considerable numbers of fish at a rather large cost. This fact, coupled with the unsuitable condition of the market fish, made the research staff decide to catch their own fish under conditions which would assure correct analysis in the course of the contemplated projects. It was decided to use trolling as the means of capture because this method required the least expenditure

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for initial equipment, the species of fish desired in the project work could be caught by trolling methods and a small research vessel was already available for this work. Consequently, a trolling survey of Hawaiian waters was undertaken and data was collected concerning fishing areas, time of maximum fish capture, seasonal changes in abundance of the various species of fish caught by trolling methods, lure capacities, bird action, sea and weather conditions, and line patterns. An outline of the purposes and results of this survey are given below.

The trolling operation was carried out with a four-fold purpose. The first purpose was, of course, the collection of fish specimens for analysis in other research projects as was outlined above. The second purpose was to determine the economic feasibility of a Hawaiian surface troll fishery under conditions as they exist today in the islands. This was done by determining the income to be expected from average trolling operations in relation to market conditions and equipment costs. Another purpose was to determine the best fishing areas for trolling around the areas of the more heavily fished local waters. This was done by correlating the catch made by the research vessel in the various areas with the time spent catching the fish and comparing these results by area. The fourth purpose was to determine the best use of trolling equipment. This was done by observation of the most effective use of trolling-line patterns, most effective type of lure for the various types of fish, value of using certain birds for locating fish, and most effec-

ive weather conditions for the various types of equipment employed.

The two boats used in this project were 45 and 65 feet in length respectively. They were both diesel-powered, single screw boats suitable to the speed and easy maneuverability essential to a successful trolling boat. Both boats had square sterns which caused a considerable amount of wake. This is considered a liability in other areas where trolling is done commercially. Typical mainland outriggers were used to get the trolling lines away from the side of the boat and also to increase the number of lines that could be used. The best outriggers were obtained from sapling eucalyptus trees which remained tough and springy. They were dried in the shade for two weeks, painted with two coats of linseed oil and varnished. A system of line lengths and line weighting was used to prevent tangles during the sharp maneuvering which is sometimes necessary when chasing a school of fish. The outermost lines were the shortest and they also carried the greatest amount of weight--about six pounds of lead wrapped about the line over a total line length of three feet. This enabled the outermost lines to be brought under the other trolling lines when being retrieved. The line lengths varied inside to outside from 120 to 180 feet. Rigging in this manner made it possible to fish a total of seven lines at one time thus allowing ample possibilities to test the effectiveness of various lures against competing lures at the same time and with the same fish, weather conditions, speed, water conditions and area.

During the course of the project, a considerable number of

artificial lures were used. As one of the aims of the project was to determine the best equiptment for local fishing, it was decided to test every type of lure that was available to the local fishing fleet. Of course, every individual fisherman has his own pet lures which are kept fairly private in design and no attempt was made to determine effectiveness of these specialized lures. however, certain individual variations upon the common commercial lures were tried with varied degrees of success. Tests were made upon the shape, color, type of hook, best fishing speed, action, and types of group trolling patterns which best suited various lures.

The majority of the trolling was done around the island of Oahu. The range of the small boats used in this work was such that the most effective use of the boats was obtained near their base of operation--Honolulu and Kaneohe Bay. Also, as one of the aims of the project was to determine the feasibility of a local commercial trolling operation, it was decided to simulate the area in which the majority of such operations would be carried out. This area had to be within easy reach of a fairly extensive operating base and a ready market for the fresh fish. Trolling boats, to be successful, must be rather small with little overhead expenses. The boats must be based near the market because ice-storage spaces would be very limited in these small trolling vessels and fish spoilage in the local climate is notably fast. The condition of the fish directly effects the price paid for the fish in the local markets.

The total catch over the length of time covered in this project may be summed up as follows: (March, 1948 to June, 1949)

TABLE ONE(1)

Month	Ono		Aku		Ahi		Kawa		Mahi		Olua		Total		Hrs.	Fish
	no	lb	no	lb	no	lb	no	lb	no	lb	no	lb	no	lb	trolled	per hr
March	0	0	4	24	2	29	16	76	8	129	0	0	30	258	29½	1.07
April	1	39	1	4	1	5	28	142	1	14	0	0	32	204	17	1.88
May	3	49	11	78	7	35	66	281	5	83	0	0	92	526	28	3.29
June	3	66	11	59	4	20	9	37	4	65	0	0	31	247	22½	1.38
July	1	17	3	18	0	0	4	19	0	0	2	18	10	72	9½	1.05
Aug.	5	97	2	15	2	15	6	31	4	57	2	37	21	252	28	0.75
Sept.	0	0	0	0	2	30	5	27	4	64	0	0	11	121	8	1.38
Oct.	0	0	0	0	0	0	92	181	6	122	0	0	98	303	16	6.13
Nov.	0	0	0	0	0	0	31	34	3	56	0	0	34	90	7	4.86
Dec.	0	0	0	0	0	0	8	43	4	22	0	0	12	65	19	0.63
Jan.	repairs		-		-		-		-		-		-		-	-
Feb.	0	0	0	0	0	0	11	28	8	58	2	67	21	153	16½	1.27
Mar.	0	0	0	0	2	31	56	180	13	104	0	0	71	315	29	2.45
Apr.	0	0	0	0	1	5	14	49	9	184	1	37	25	275	17½	1.43
May	5	210	0	0	1	6	0	0	17	314	0	0	23	530	32½	0.71
June	2	67	14	139	1	15	4	14	15	272	1	9	37	516	27	1.37
TOTAL CATCH	20	545	46	337	23	191	350	1136	101	1544	8	108	548	3927	307	

Total yield:

1.79 fish per hour of trolling
12.79 lbs. of fish per hour of trolling

The following chart is the summary of the monetary return for the amount of fish caught for each month during the course of the project. The indication of the favorability of fishing during a certain month is to be found in the column listed as Amount/hour. The higher this value, the more favorable the month for trolling as far as the financial aspect is concerned.

TABLE TWO(2)

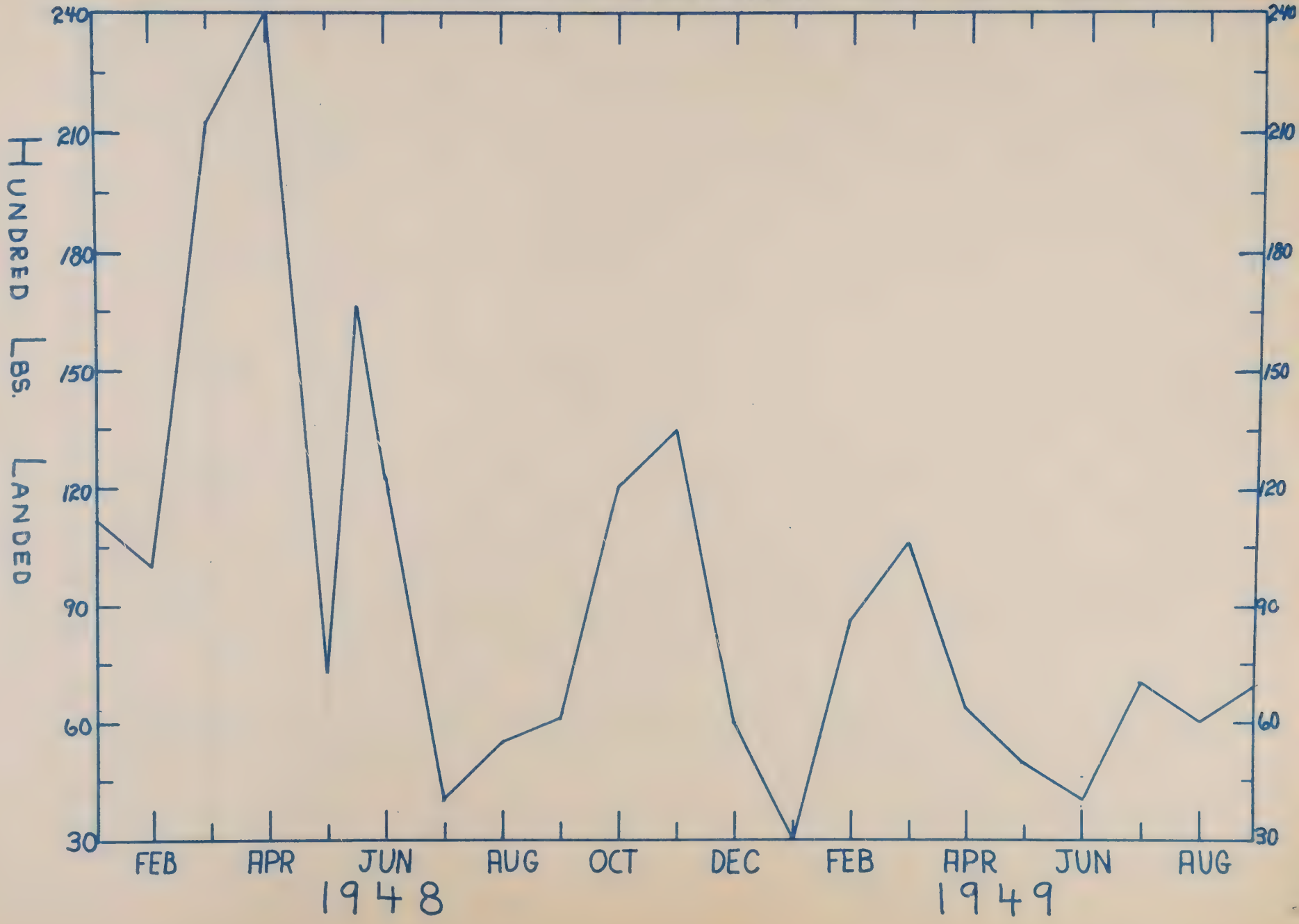
Month	Ono	Aku	Ahi	Mahi	Kawa	Ulua	Total	Amt./Hr.
March	0	4.56	12.18	51.60	15.96	0	84.30	2.95
April	13.65	0.72	2.25	5.18	25.56	0	43.36	2.79
May	16.17	14.82	17.85	30.71	59.01	0	138.56	5.03
June	17.82	8.85	8.00	24.05	6.66	0	65.38	2.91
July	3.91	2.71	0	0	4.56	7.20	18.37	1.83
Aug.	27.16	2.10	6.30	22.23	6.20	15.54	79.53	2.84
Sept.	0	0	12.60	26.88	5.94	0	45.42	5.67
Oct.	0	0	0	47.58	23.23	0	70.81	8.13
Nov.	0	0	0	23.52	6.12	0	29.64	4.42
Dec.	0	0	0	10.12	12.90	0	23.02	1.21
Jan.	Repairs							
Feb.	0	0	0	24.36	7.84	27.47	59.67	3.62
Mar.	0	0	16.12	37.47	55.80	0	109.36	3.77
April	0	0	2.40	60.72	14.70	16.28	94.10	5.38
May	73.50	0	2.88	103.62	0	0	180.00	5.54
June	23.45	28.70	4.50	89.76	2.10	3.69	152.20	5.63
TOTAL	175.66	62.45	85.08	522.16	282.22	70.18	1193.72	

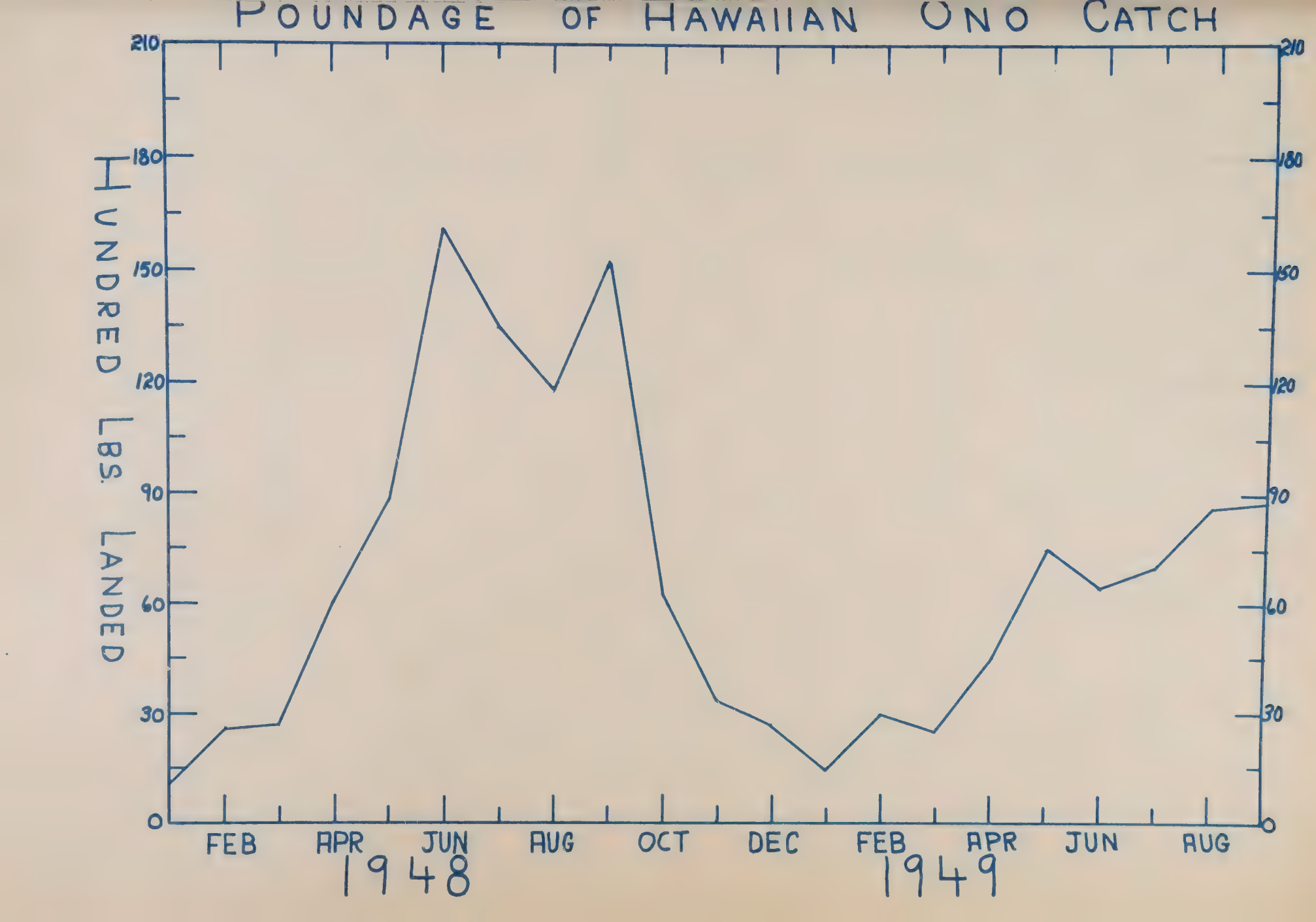
Realized $3.88 per hour of trolling

An analysis of the above chart would indicate the fall of the year as the best time economically to carry out trolling operations with October as the peak month. Early spring and summer are also fairly favorable times to carry out trolling operations. The overall picture of the economic return from trolling operations indicates that surface trolling is probably not a suitable fishing method in local waters when the price of fish is at the present level and when operating expenses remain at the present high rate. If a rate of income approaching three times the amount realized in this project could be sustained, it is probable that trolling could become a profitable method of local fishing to a small trolling vessel. Normal trolling techniques such as are used on the West Coast do not seem to be adequate to sustain a fish catch which would even approach the covering of the operating costs of a crew and boat suitable for trolling operations. Revised techniques, such as trolling at depths now exploited only by flagline gear, using a double-ended boat with little wake and development of new lures might increase the catch to a point that would prove profitable, but these techniques have not yet been tried in local waters and will be investigated in the future. The above chart also indicates that mahimahi provide the major source of income to the troller although lower-priced tuna constitute the bulk of the poundage of fish landed.

Included in the report below are three charts showing the actual total landings in all Hawaiian ports during February, 1948 to September, 1949 of the several species of fish which constitute the bulk of the trolling catch.

POUNDAGE OF HAWAIIAN KAWAKAWA CATCH




POUNDAGE OF HAWAIIAN ONO CATCH
HUNDRED LBS. LANDED
210
180
150
120
90
60
30
0
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
1948
1949

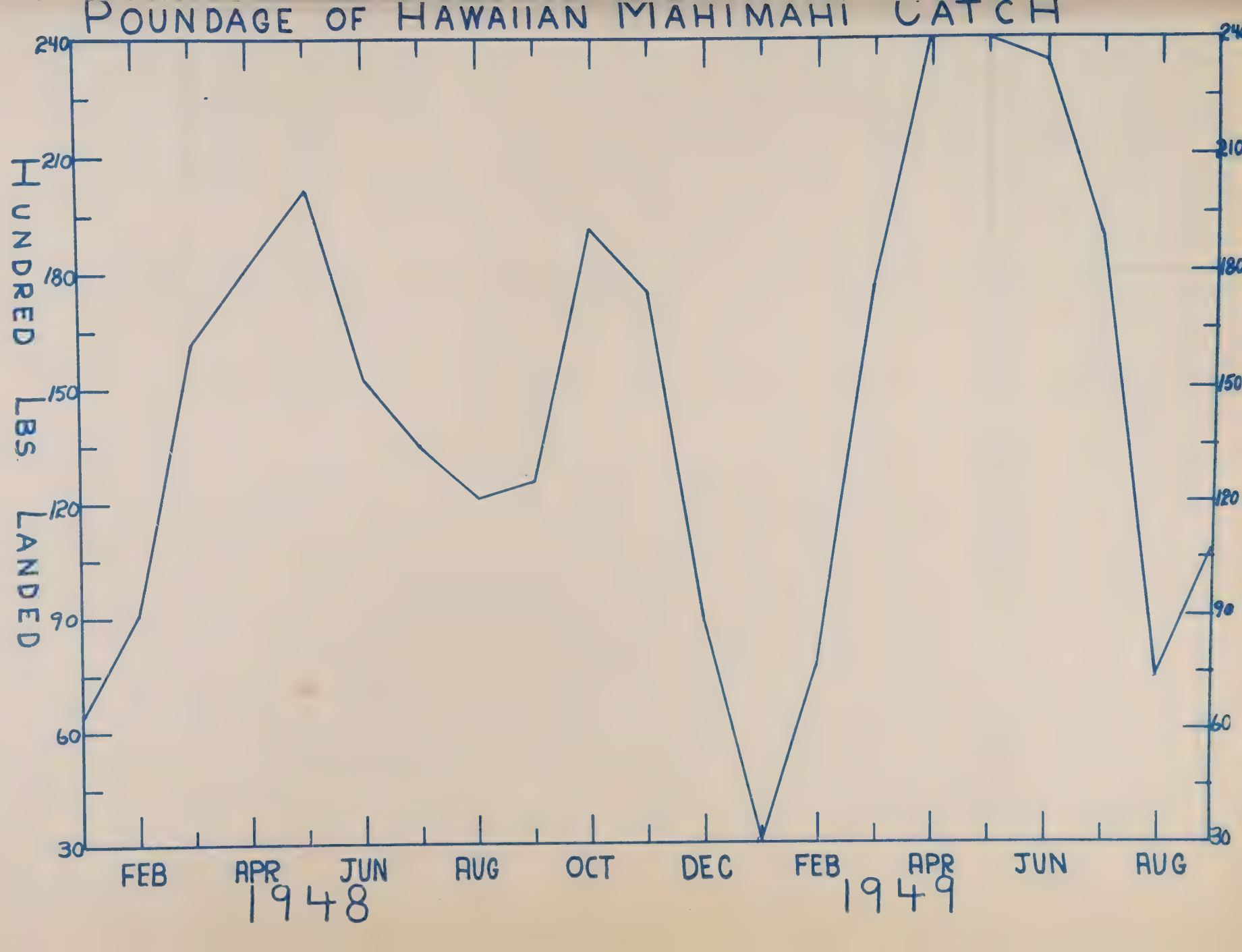

POUNDAGE OF HAWAIIAN MAHIMAHI CATCH
HUNDRED LBS. LANDED
240
210
180
150
120
90
60
30
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
1948
1949

TABLE THREE(3)

Summary of Landings of Kawakawa, Mahimahi and Ono in Hawaiian Ports. January, 1948 to September, 1949

Month	Lbs. Kawakawa	Lbs. Mahimahi	Lbs. Ono
Jan.	11,301	6,637	932
Feb.	10,339	9,009	2,6[illegible]
Mar.	21,469	16,050	2,619
Apr.	25,017	26,386	6,[illegible]
May	7,210	20,378	3,4[illegible]
June	12,514	15,505	16,[illegible]
July	3,718	13,285	13,[illegible]
Aug.	5,489	12,121	11,341
Sept.	6,059	12,525	15,340
Oct.	12,140	19,374	6,102
Nov.	13,784	17,373	3,522
Dec.	6,079	8,975	2,750
Jan.	2,132	2,930	1,924
Feb.	8, 839	7,765	3,354
Mar.	9,935	17,456	2,036
Apr.	6,369	24,366	4,468
May	5,122	28,944	7,1[illegible]
June	3,493	23,743	6,[illegible]
July	6,782	18,502	8,8[illegible]
Aug.*	5,453	8,874	5,07[illegible]
Sept*	5,898	7,423	5,0[illegible]

Ulua remain fairly constant over the year in their abundance in the commercial landings. There are indications, however, that local fishing practices distort any picture of the availability of this fish by examination of the commercial fish landings. Hence, no attempt has been made to determine availability of ulua by plots of the fluctuations in the commercial landings. There are also indications that the amount of kawakawa landed is somewhat correlated with the price of tuna during the summer months so a distortion of the availability picture given in the previous graphs is liable to be slightly biased by this factor. The graphs show that the mahimahi has a tendency to be more common in the early spring-late winter period and fall with a slump in abundance in the mid-summer and mid-winter. Examination of catch records disclose that the larger mahimahi tend to be taken during the late-winter. The ono has a very low abundance in local waters in the winter, but it becomes rather common in the catches made in the mid-summer months. The kawakawa seems to show a similiar pattern to the mahimahi in that it is most abundant in the spring and fall with a slump in abundance during the mid-summer and mid-winter. Trolling operations for ahi seem to show the mid-summer season as the most favorable. Aku seem to have a summer abundance and an erratic rise in availability in mid-winter with an early spring and late fall slump in abundance. It is interesting that none of the fish normally caught by trolling show a seasonal disappearance from local waters although all of them show increased scarcity in the months of January and February. However, this decrease in the supply of fish is compensated by the fact that the price of fish makes the decreased catch more valuable to the fisherman. As

the price of mahimahi is highest at the peak of the scarcity of fish, and therefore the peak of prices for fish, it would seem reasonable to concentrate on catching mahimahi during the winter months. On the other hand, due to the abundance of ono in the summer and the high price of this fish, it would be best to concentrate on catching ono in the summer. Tuna should also be sought mostly in the winter because the extreme abundance of aku in the summer causes a very low summer price.

Records were kept on the effectiveness of the various lures which were used in this investigation. A total number of nineteen different lures were tried with varying line-patterns, and as the fishing progressed it was evident that certain lures were more effective than others. All of the lures except a special white flying-fish lure were purchased from vendors of commercial and sporting artificial lures in Honolulu. A record was made of the total time each lure was fished and the total number of fish each lure caught. In order to arrive at an estimation of the relative effectiveness of the various lures, it was necessary to determine the number of fish each lure caught per normal fishing day. Exact amount of fishing time was recorded for each lure. This total time was divided into 10 hour periods in the analysis in order to approximate an average amount of time spent trolling in one fishing day. The results of this analysis of the effectiveness of fishing lures is presented below in table form.

TABLE 4

NO. OF FISH CAUGHT BY VARIOUS TROLLING LURES

(February, 1948 — June, 1949)

Lure No.	AHI		AKU		ULUA		ONO		MAHIMAHI		KAWAKAWA		No. Fish per 10 hrs	Total hrs Fished	Lure Best For:
	No.	No. per 10 hrs	No.	No. per 10 hrs	No.	No. per 10 hrs	No.	No. per 10 hrs	No.	No. per 10 hrs	No.	No. per 10 hrs			
1	9	0.5	17	0.9	1	0.06	3	0.2	25	1.4	98	5.4	8.5	180.5	Kawakawa
2	2	1.0	3	1.6			2	1.0	6	3.1	9	4.7	11.6	19	Kawakawa & Ahi
3	2	0.3	1	0.1			1	0.1	5	0.9	18	3.5	5.3	51	
4					3	1.2	9	3.5	1	0.4	1	0.4	5.4	26	Ono
5					1	0.9	3	2.6	2	1.7	1	0.9	6.1	11.5	
6	1	0.2	1	0.2					7	1.1	85	13.0	14.5	65	Kawakawa
7									8	5.3	19	12.6	18.0	15	Kawakawa
8									3	1.7	4	2.2	3.8	18	
9									1	1.4	1	1.4	2.9	7	
10									15	4.8	16	5.1	10.0	31	Kawakawa & Mahimahi
11							1	0.6	7	3.9	8	4.4	9.0	18	" "
12					6	7.5					6	7.5	15.0	8	Ulua & Kawakawa
13													0	7.5	
14	4	0.5	3	0.4			2	0.3	4	0.5	18	2.0	3.5	87.5	
15			2	0.4					2	0.4	3	0.6	1.4	49.5	
16													0	14	
17					1	1.4							1.4	7	
18									3	4.2	2	2.8	7.1	7	
19									1	2.5			2.5	4	

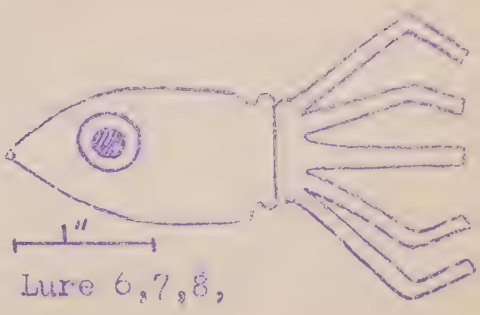
A description of the lures and simple outline drawings are given below.

TABLE 5

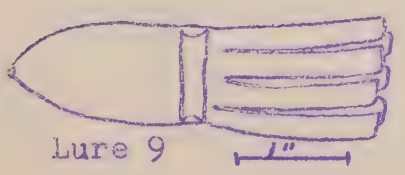
1. Red and white Jap feather with pearl eye---steady runner
2. Plymouth rock " " " " " " "
3. Small all-white " " " " " " "
4. Large " " " " " " " " "
5. Varicolored " " " " " " " "
6. Red-bodied metal squid with rigid, white tentacles---steady runner
7. Blue bodied metal squid with rigid, white tentacles---steady runner
8. Silver " " " " " " " " "
9. Yellow, plastic-bodied squid with pliable tentacles---steady runner
10. Small, blue-bodied wooden flying fish with plastic wings---jumper
11. Large " " " " " " " " "
12. Large white plug with stiff plastic wings---jumps every 100-300 feet
13. Jap bone jig---steady runner
14. Red rubber inner-tube squid with metal head and pearl eye---jumps every 100-300 feet
15. Blue and white Jap feather with pearl eye---jumps every 100-300 feet
16. Red and white metal head jumping feather---Jumper
17. Pearl spoon---steady runner
18. All red feather " "
19. Blue and silver large wooden plug---jumper

Illustration of the general types of lures used for trolling

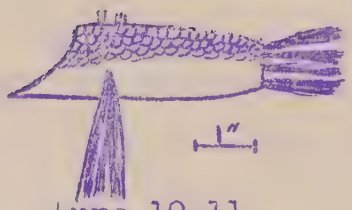
Lure 1,2,3,4,5,14,15,18



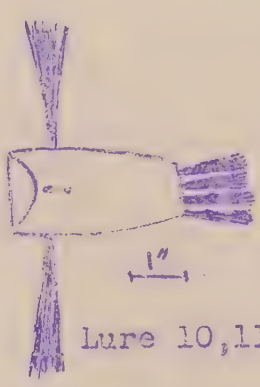
Lure 6,7,8,



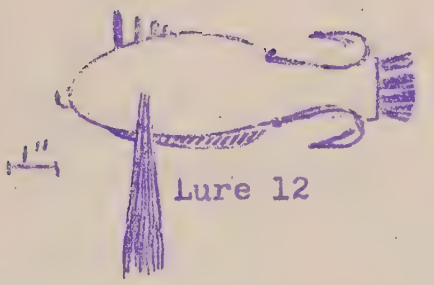
Lure 9



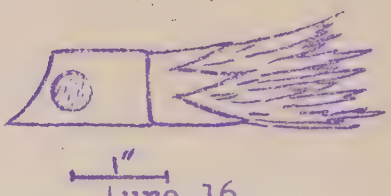
Lure 10,11



Lure 10,11

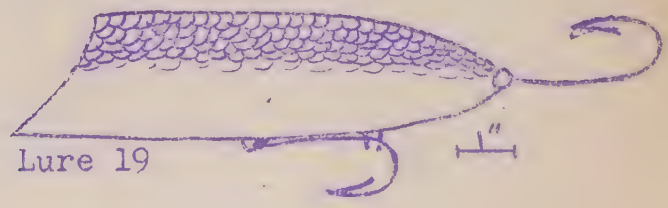


Lure 12



Lure 16

Lure 13



Lure 19

From the analysis it is evident that eight lures were particulary effective for one or more of the six fish caught most frequently by trolling. These lures are:

red and white feather——for kawakawa
plymouth rock feather——for kawakawa, aku, mahimahi, and ahi
very large, all white feather——for ono
red metal and white rubber squid——for kawakawa
blue metal and white rubber squid——for kawakawa
small blue wooden flying fish——for kawakawa and mahimahi
large blue wooden flying fish——for kawakawa and mahimahi
all white wooden flying fish plug——for kawakawa and ulua

The above lures were chosen as particularly effective because they caught more fish per fishing day than any of the other 19 lures used in this project for the various species of fish recorded. More work needs to be done on the effectiveness of various lures with varying line-patterns and at varying depths. All of the fishing done in this project thus far has been done at or near the surface. Discussion with fishermen from the Pacific Northwest indicates that there is a definite correlation between wake-size of the trolling vessel and fish catch. There it is felt that a trolling boat* should have the least wake possible and hence there has been developed a double-ended type of boat built specifically for trolling. As the above lures were being used, two different types of hooks were tried. The first type was the simple single hook with a straight shank and heavy trolling barb. The second type of hook used was the American albacore-type double hook. The double hook was found to be much more effective in holding hooked fish during the landing struggle while the boat was necessarily still underway at a considerable speed.

There is some possibility that the fish may prefer a particular color. This

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*Trolling for sea-run Salmon at various depths.

preference may be due to similiarity to the color of the natural prey of the fish or it may be due to visibility of the color through water--hence allowing the fish to be attracted at a farther distance and adding to the total area being fished by any single trolled lure. Preliminary tests have shown that a color preference for bright metallic red exists. These tests were carried out with rubber and metal squid of the same pattern, different color and fished at the same time.

During the course of the trolling operations, notes upon the weather and sea conditions have been carefully kept. Of the three major categories of weather--dark, cloudy, rainy; partly cloudy; and clear; it was found that the partly cloudy days were best for trolling but the success of catching fish could be slightly altered by changing lures to suit the type of weather. It was found that a significant difference in catch could be correlated with the condition of the sea. The flat calm sea was fished for 56 hours and only 14 fish were caught. Fairly choppy seas were fished 69 hours and 197 fish were caught. Very rough seas were fished 100 hours and 172 fish were caught. Unusual sea conditions caused by very local conditions were not considered in the analysis. On a comparative basis, this shows that calm days have a rating of 0.25 fish per hour; choppy days have 2.81 fish per hour; and very rough seas have 1.72 fish per hour. The waters fished on the above analysis were on all sides of the islands of Kauai, Oahu, Molokai, Maui, Niihau, Kaula, and Hawaii. This would indicate that the choppy days were the best for trolling and that it is almost a waste of time to do much trolling on very flat, calm days, considering a commercial point of view. All days have a high enough rating to justify sport fishing at any time.

Given below is an analysis of the relative merits of the various areas that

were fished by trolling methods. The information is weighted in many ways by the fact that not enough representative trolling was possible to be able to get a true picture of the fishing conditions of these areas under all conditions. This table is only an indication of the tendencies—not an accurate measure of the true quality of the fishing areas.

Comparison of the Various Areas Fished by Trolling Methods

TABLE 6

Area	Hours Trolled	Total No. Fish Caught	No. hours	Species most commonly taken
...--Kaula Rock	5	17	3.4	Ono and Mahimahi
... coast of Kauai	7	17	2.4	Ono, mahi, ahi, kawaka
...el between Kauai and Oahu	16	8	0.5	Mahimahi
... Pt. tide rip, Oahu	9	33	3.7	Kawakawa, mahimahi
...e area, Oahu	16	9	0.6	Kawakawa, mahimahi
...r's Pt. to Koko Head, Oahu	31	19	0.6	Kawakawa, aku, ono
...0 miles SW from Honolulu	12	17	1.4	Mahimahi
...u Pt., Oahu	7	15	2.1	Aku, mahimahi
...Manu to Rabbit Island, Oahu	71	298	4.2	all species
...uu Pt. to Kokohead, Oahu	29	101	3.4	all species, Ono
...kai channel-Penguin Bank	25	40	1.6	Mahimahi, aku, ono
... Pt.-Kaunakakai, Molokai	14	15	1.1	Kawakawa, mahimahi
...ward Maui to Kahului	8	4	0.5	Kawakawa, aku
...ina, Maui--Lanai--Kahoolawe	28	12	0.4	Kawakawa, aku, ono
...el between Maui and Hawaii	8	1	0.1	Ono
... area near Kailua, Hawaii	14	8	0.6	Aku, ono, mahimahi

From the above analysis it is evident that windward Oahu and Kaula-Niihau area seem to show advantages to trolling operations. It is interesting that the majority of the fish caught trolling were taken around points of land which produced a considerable tidal rip. It is known that these tidal rip areas tend to be collecting places for the small food animals and hence it is to be expected that the type of fish caught trolling would also tend to collect in these areas.

During the course of this project, records have been kept of the exact location of every catch made by surface trolling. A summary of the area of the total catch, separated into seasonal times of capture, is given below:

KEY TO THE SYMBOLS SHOWN IN THE FOLLOWING CHARTS OF TOTAL TROLLING CATCH

indicates location of single KAMAKUMA catch

indicates location of single KAKU catch

indicates location of single ULUA catch

indicates location of single AHI catch

indicates location of single MAHIMAHI catch

indicates location of single AKU catch

indicates location of single ONO catch

MARCH
1948

10 MILES

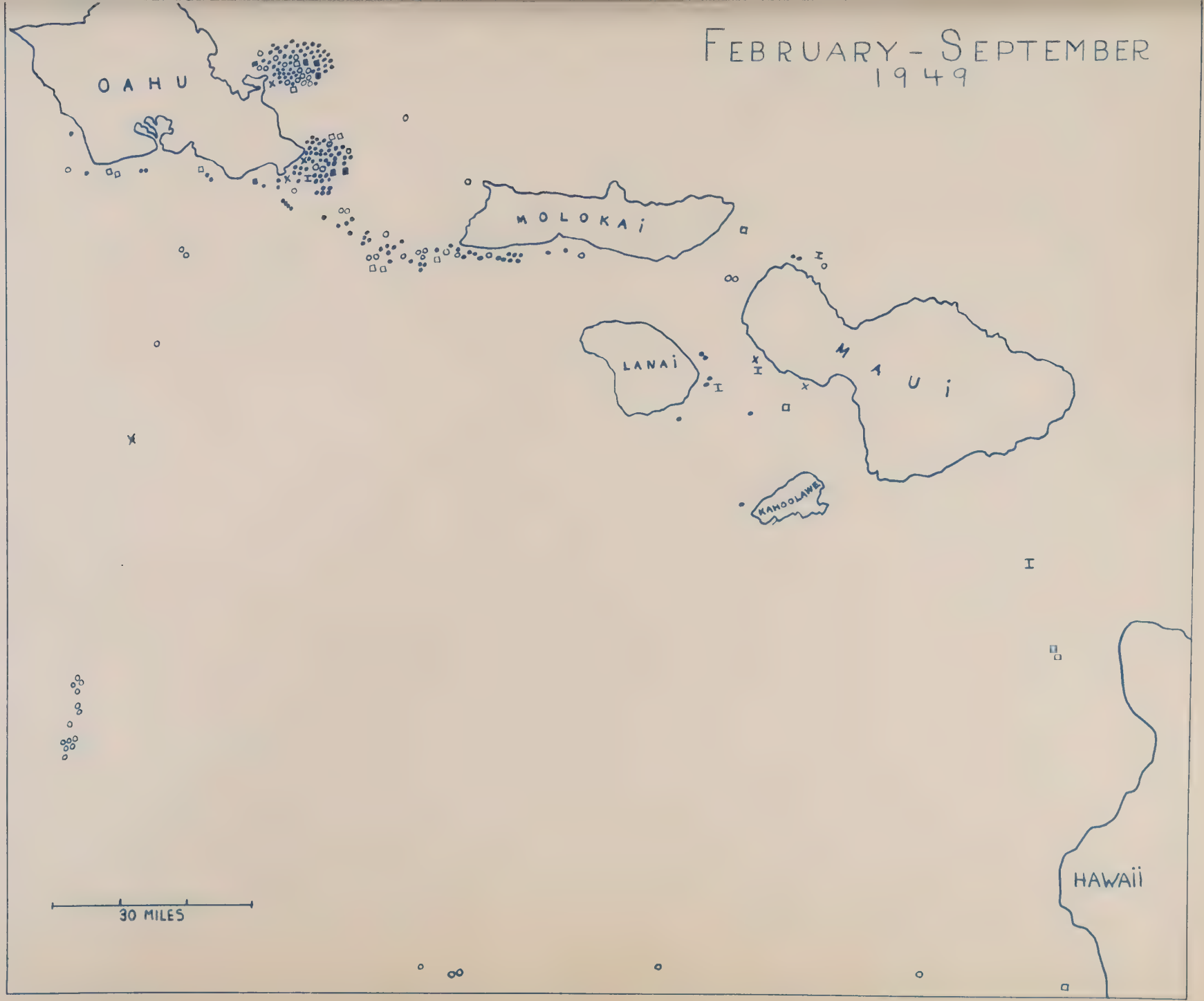
APRIL - JUNE
1948

1148

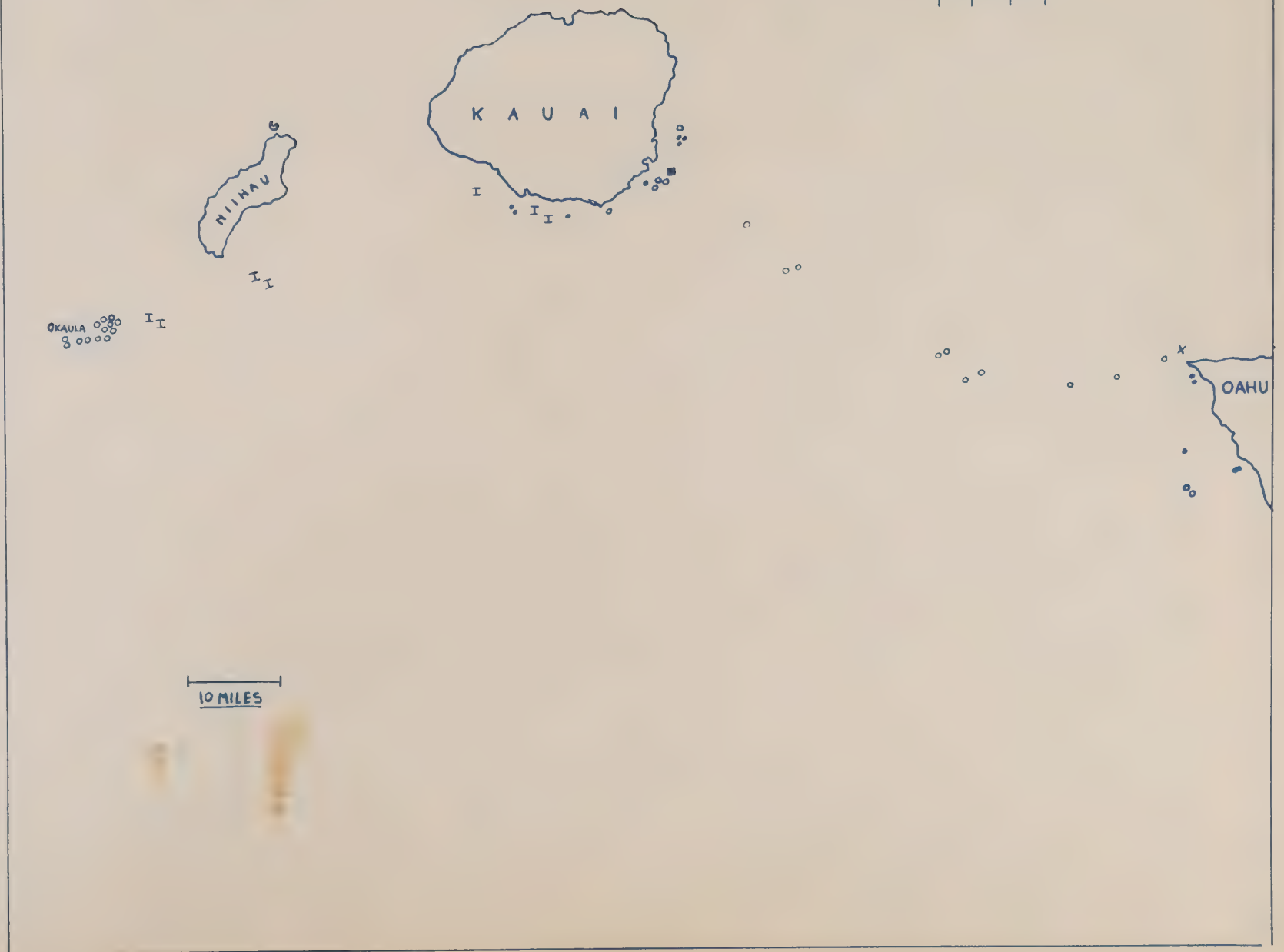
10 MILES

1948

10 MILES


FEBRUARY - SEPTEMBER
1949
OAHU
MOLOKAi
LANAi
MAUi
KAHOOLAWE
HAWAii
30 MILES

FEBRUARY - SEPTEMBER 1949



Observations were made to determine the use of birds in locating fish. It was found that tuna schools were usually located under closely-packed flocks of "fluttering" noddy and sooty terns. These birds hovered about 3 to 10 feet over the feeding tuna and often dipped down to the water to feed upon the small food animals which were driven to the surface by the tuna. On the calm, Kona Coast of Hawaii, tuna schools are indicated almost entirely by the presence of shearwaters. The terns seem to prefer the windy channels and windward sides of islands with the exception of Waianae, Oahu. Mahimahi are usually indicated by diving gannets or boobies which feed upon the flying fish being chased into the air by the fish. Frigate birds also soar high in the air over mahimahi schools and it is always worth while fishing in an area where a frigate bird is seen to dive at the water. In general birds are a big help in finding the concentrations of fish and even determining the kind of fish present, but trolling strikes are apt to happen anytime regardless of a lack of birds. Mahimahi and ono are prone to collect around floating objects in the water and logs, boxes and other flotsam of any size should be fished.

In summary, this preliminary trolling project has shown that a commercial surface trolling fishery around the Hawaiian Islands is probably not economically feasible under present conditions. The methods used, gear available locally, operating costs and market conditions indicate that not enough poundage of fish could probably be landed to ensure a steady profit. The aspect of a change in equipment such as an especially designed, high speed, double-ended boat; and exploitation of new areas, such as deep water near the thermocline area now fished by flagline fishermen indicates that a trolling fishery in the future is not impossible. It was found that certain areas produced more trolling strikes than others; choppy, partly cloudy days were optimum; and certain lures held

special favor with various species of fish. A study of the relative merits of different areas in providing good fishing seem to show that the windward sides of most islands in the area near a channel between islands produces the best fishing. The fish normally taken by trolling show a definite fluctuation of abundance with the best months for trolling from May to October. However, the poundage of troll caught fish coupled with their year-around availability on smooth-water fishing grounds seems to indicate certain advantages of Hawaiian waters as an attraction to people interested in sport fishing.

A POWER HAULER FOR FLAGLINE

I. INTRODUCTION

Recently, the Division of Fish and Game entered on a program of research concerned with the relationship of the large tunas and marlins (Ahi and A'u) and certain easily determined oceanographic phenomena. In order to collect the information needed for this program, it was necessary to go flagline fishing, and while fishing, take periodic temperature readings along the flagline to a depth of 450 feet. An article will be issued later on the results of this study; its mention here is purely introductory and to account for our venture into flagline fishing. However, it become necessary to build a flagline, and then desirable to build a line hauler in order to handle it.

The present article is concerned with a description, the method of operation, and practical comments on the use of the line hauler put aboard the Makua. This article was written because some of the flagline fishermen have expressed an interest in the line hauler of the type used by the Division of Fish and Game.

The line hauler described here is not new or original, neither is its application to flagline fishing; it is borrowed from descriptions and pictures of line haulers used by the flagline fishermen of Japan. Whether or not it is adopted generally for fishing operations in Hawaiian waters may be determined by circumstances of an imponderable kind, such as prejudice on the part of fishermen, or other; however, to question the practicality of the hauler is to lose sight of the fact that the Japanese have found it not only completely practical but essential for flagline fishing for many years.

II. DESCRIPTION OF THE LINE HAULER

There are the following basic components to the line hauler:

(1) a drive wheel which is turned by power and serves to pull the line in, (2) an idler wheel which rides against the driver under some pressure to prevent line slippage, (3) a fairlead pulley to center the line and (4) line guides on the rail of the boat. The flagline is led through the line guide on the rail, through the fairlead pulley, then around the drive wheel and between it and the idler wheel, whence the line falls free to the basket. The photographs and diagram below may be easier to understand than the description above. The principal advantage of this type of line hauler as compared to the gypsy head, as now used aboard some flagline vessels, lies in the fact that the hauler brings in the line without someone pulling on it, and hence at a speed greater than a man can possibly pull when desired.

Since the hauler is positive in action, pulling the line in as long as it runs, it must be equipped with a convenient means of starting and stopping, and additionally, a means of speed control is highly desirable. The line hauler described here was powered by a 3 h.p. electric motor which, in turn, was handled through a drum type motor controller. This made it possible to regulate the speed and to start or stop the hauler very simply. However, an electric drive is not a particularly practical power source on an average flagline boat; the vessel used for this program by the Division of Fish and Game had a 30 K.W. diesel driven generator which made an electric drive the simplest to use. In most instances, a hydraulic drive off the main engine would seem to fit all requirements best.

SPECIFICATIONS FOR THE LINE HAULER ABOARD THE M. V. MAKUA

Driving Wheel: With rubber tire 12 inches in diameter by 4 inches wide; variable from 0 to 287.5 R.P.M. in either direction.

Idler Pressure Wheel: Built up of rubber discs 4 inches in diameter; width same as driving wheel.

Fairlead wheel: Solid brass, 5 inches in diameter; thickness same as driving wheel.

Stand: 8" pipe about 4' long, welded to 1/2" boiler plate which is bolted to the deck.

Power: A three horsepower electric motor, driving through two Ford V8 rear end transmissions, each giving a 3 to 1 reduction in speed and a 90° turn to the shaft direction. The motor was mounted below deck with a chain coupling to the first V8 rear end. A shaft served to transmit the power up the interior of the pipe stand to the second V8 rear end at the top of the stand which drove, in turn, the driving wheel.

Control: A drum type controller with 2 armature and 10 field control points in either direction of rotation.

Performance: A 3 horsepower motor driving a wheel 12 inches in diameter at 237 R.P.M. will give the wheel a rim speed of about 900 ft. per minute, the same speed will be given to a line pulled over the wheel, and a line pull of about 100 pounds. This represents a higher line speed than can ordinarily be used and perhaps a line pull that is too low. If five knots be taken as a maximum speed for picking up a flagline; then the driving wheel should be given a rim speed of 500 ft. per minute which with a 3 horsepower, would give a line pull around 180 pounds. This is plenty of pull, and ordinarily would never be used, but worth having none the less for a possible emergency. These line speeds and pulls are maximums and would rarely be employed under practical conditions of operation. At a 500 ft. per minute line speed, one 180 fathom basket of flagline would be aboard the boat in slightly more than two minutes, and while this may be an impractically high speed

for handling the float and hook lines, it is one that may be used intermittently to good advantage while picking up a flagline.

Method of Operation: The flagline is set conventionally, i.e., it is laid over the side or the stern of the fishing vessel, basket by basket with the vessel under way. It is picked up by threading the main line through the rail fairlead and then to the fairlead pulley, over the drive wheel through the point of contact between it and the idler wheel. From here it is allowed to drop into a flagline basket set directly below on deck, where it is coiled and stored. Flagpoles and buoys are detached from the main line at the rail, and hook and buoy lines are coiled separately by hand. These branch lines are not, however, detached from the main line, but when coiled are laid in the basket with the main line.

Line Hauler Design: The photographs and diagrams given at the end will supply a clear idea of the general arrangement and layout of a line hauler for flagline. The following points should be kept in mind when building one:

(1) Source of Power: It may be driven by line shaft from the main engine, a hydraulic drive from the main engine, or by a separate power unit. A separate power unit may be either electrical or internal combustion (gasoline).

(2) Speed Control: This is a highly desirable characteristic to incorporate in any line hauler. If the drive is through a line shaft from the main engine or a gasoline auxiliary, then a method of speed control by changes in gear ratios and a clutch may be essential. Both hydraulic and electrical drives permit

simple and complete systems of speed control.

(3) Performance specifications: It is suggested that a line hauler for flagline should be capable of the following performance: (a) A complete range of speeds from zero to maximum in either direction of rotation; (b) A maximum hauling speed of 400 or 500 feet of line per minute; (c) A line pull of 150 pounds or more.

(4) Recommendations: Of the various methods of powering a line hauler, a hydraulic drive powered by the main engine of the boat would seem to fit all requirements best. A line shaft drive would appear to be a poor second choice. These recommendations are based on conditions aboard the average flagline vessel. For additional information, it is suggested that the Division of Fish and Game be contacted.

Figure 1

View of main drive wheel, rider wheel, and guide wheel of the flagline hauler on the M. V. MAKUA.

Figure 2

Flagline hauler on the M. V. MAKUA in use. The line is being coiled on deck.

Figure 3

Diagram of a Japanese flagline hauler, which is essentially the same as that aboard the M. V. MAKUA. A line hauler of this design is aboard the M. V. Hugh M. Smith, operated by the Pacific Oceanic Fishery Investigations out of Honolulu.